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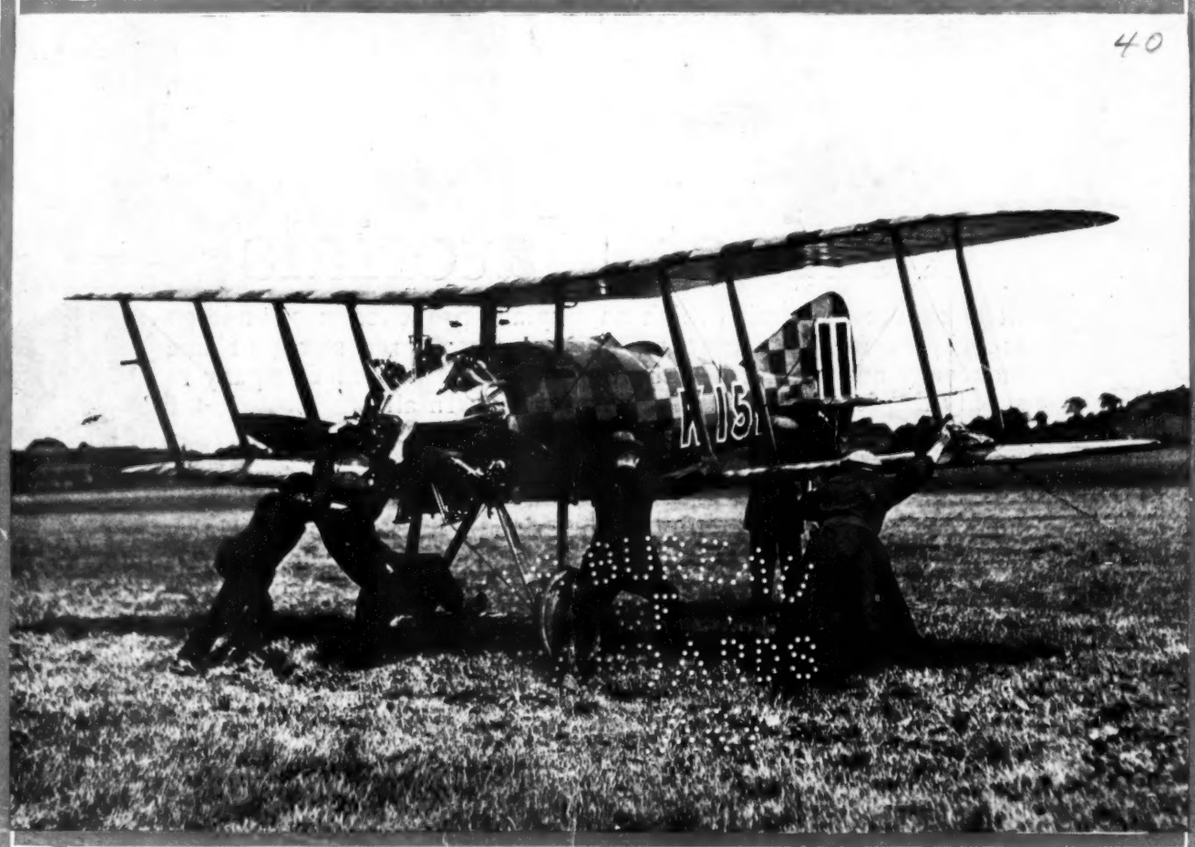
AVIATION AND AERONAUTICAL ENGINEERING



A British Racer: The Nieuport Nighthawk, with A.B.C. 320 Hp. Engine
(c) Underwood & Underwood

VOLUME VII
Number 1

SPECIAL FEATURES

METAL CONSTRUCTION OF AIRCRAFT
THE B.A.T. TRANSPORT AIRPLANE
COURSE IN AERODYNAMICS AND AIRPLANE DESIGN
PRODUCTION OF HELIUM FOR USE IN AIRSHIPS
INDEX TO VOLUMES I-VI

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PUBLISHED SEMI-MONTHLY
BY
THE GARDNER-MOFFAT CO., INC.
HARTFORD BUILDING, UNION SQUARE
22 EAST SEVENTEENTH STREET, NEW YORK

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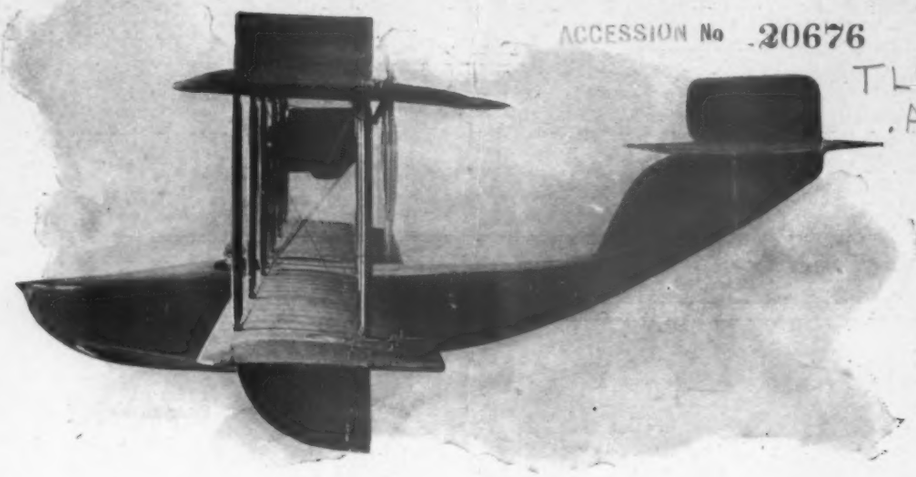

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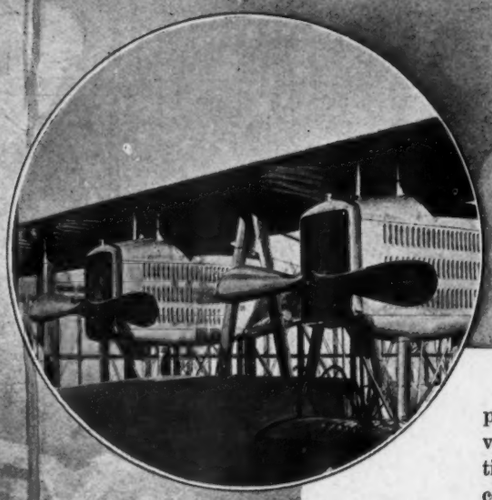
THE TWIN MOTORED PLANE



The twin motored plane is a war-time development—yet a practical installation that is certain to be adopted in the designing of many commercial airplanes.

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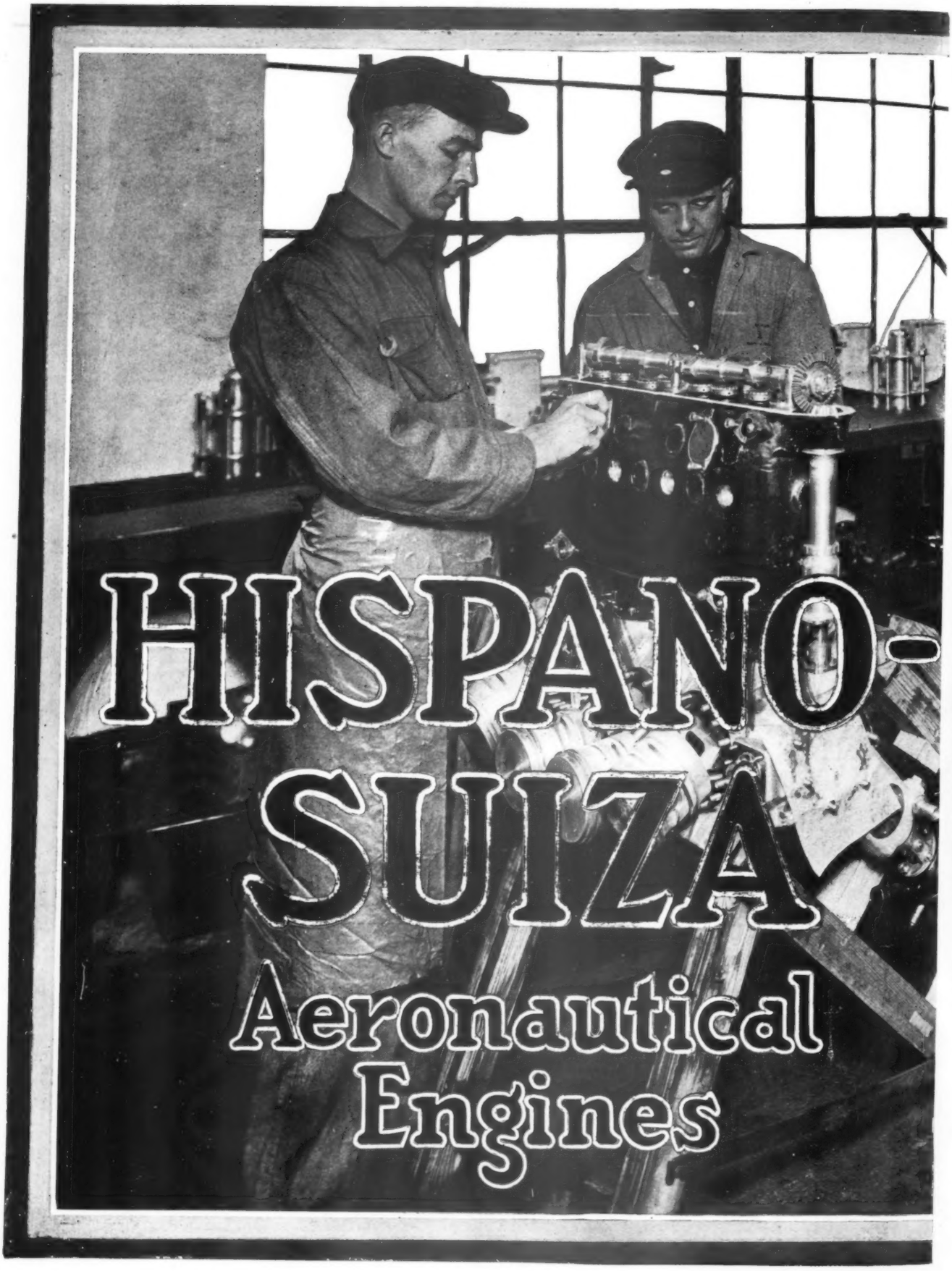
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It is more than an alloy or a group of alloys, because *Lynite* foundry practice is just as essential as *Lynite* formulae to the production of *Lynite*.

It is more than any single part or number of parts, because it stands not alone for a product but also for a service—the kind of service that can be given only by a large, forward-looking organization which does not simply take account of today's production but strives, through scientific research, to develop tomorrow's possibilities.

Fully to understand the meaning of *Lynite* you must know that to a great degree it represents pioneering in the field of aluminum alloys.

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It remained for the makers of *Lynite* largely to devise or perfect, by scientific means, the methods and processes through which the countless difficulties met in the making and casting of aluminum alloys were overcome.

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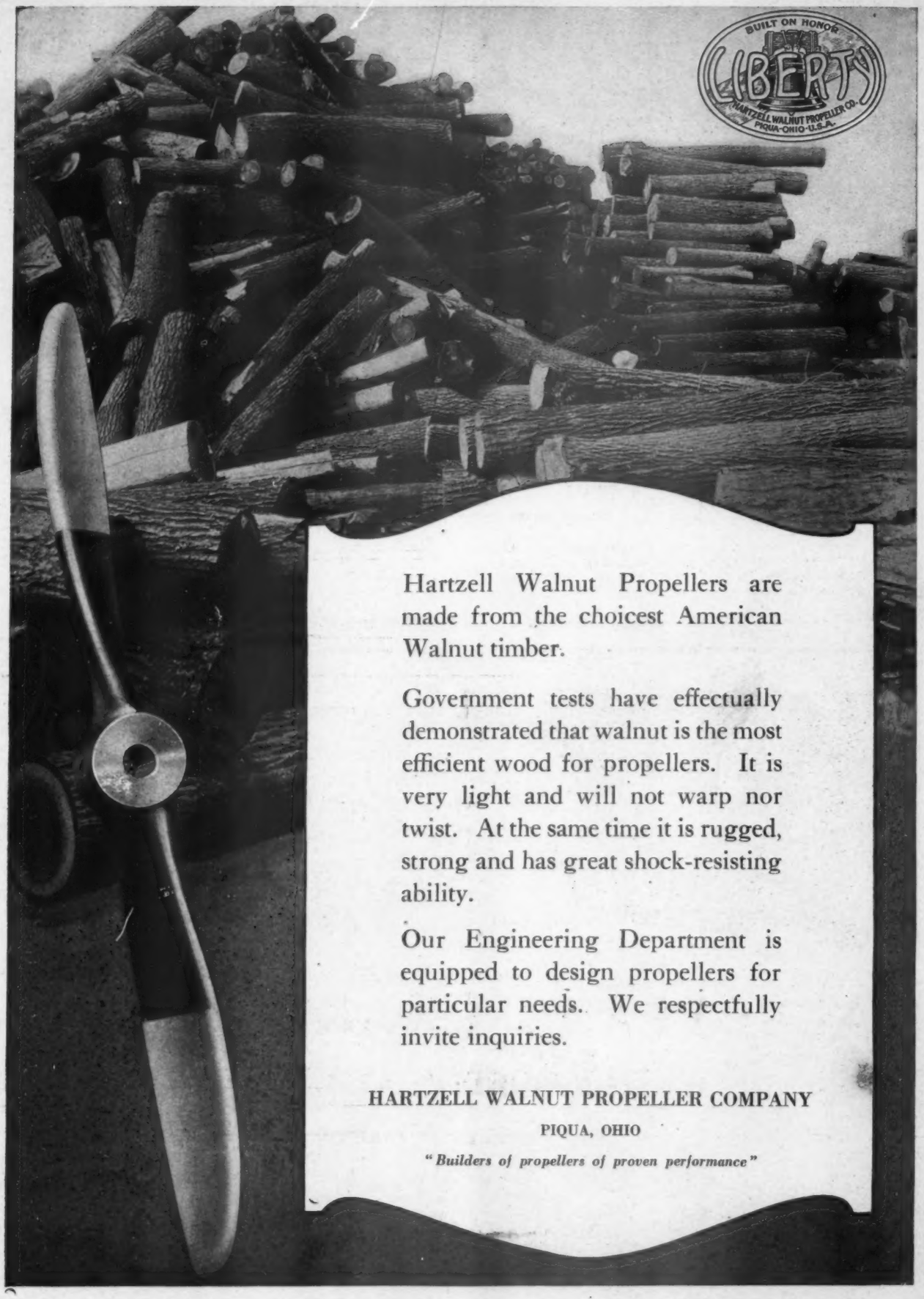

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"Builders of propellers of proven performance"

AUGUST 1, 1919

AVIATION
AND
AERONAUTICAL ENGINEERING

VOL. VII. NO. 1

Member of the Audit Bureau of Circulations

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THE GARDNER - MOFFAT COMPANY, Inc., *Publishers*

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TRY to revolve a tapered stopper in a bottle **while pressing inward.** The harder you press, the harder it turns, because of the wedging action with its resultant friction.

Repeat this operation with the ball bearing illustrated, holding the outer member in one hand and rotating the inner member **while pressing inward** as before.

You find that the ease of rotation is not impaired by the end thrust. The ball bearing turns quite freely, for the New Departure angular contact bearing absorbs end thrusts without wedging action and its consequent frictional drag.

The **ball** type is the **only** form of bearing which resists these end-on loads in modern machinery without loss of power due to the friction of wedging.

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AERONAUTICAL ENGINEERING

ALEXANDER KLEMIN
TECHNICAL EDITOR
LADISLAS D'ORCY
ASSOCIATE EDITOR
GEORGE NEWBOLD
BUSINESS MANAGER

Vol. VII | August 1, 1919 | No. 1

THE third anniversary of AVIATION AND AERONAUTICAL ENGINEERING is a fitting moment to review the progress which the last three years of aeronautical work have produced, and which the intense demands of war have so accelerated.

In that branch of the art, without which all other effort would ultimately be without object, namely navigation, there have been immense strides. Not only have navigational problems in the air been simplified and a knowledge of navigational principles become the stock in trade of every good pilot, but there has been added to our navigational instruments the radio-direction finder. This instrument which was not even thought of in 1915 now places the pilot in a position to defy fog or clouds, and provided he can keep flying at all will bring him to his destination in any kind of weather.

Then the turn indicator has come to the fore. Based on the simplest of principles, namely the varying pressure of the wind on the two edges of a turning wing, it will give the pilot an immediate indication of even a tendency to a turn. With the compass and the turn indicator the pilot can keep on a straight course, excepting that a side wind may cause him to drift. But if he is flying straight by compass and turn indicator, the radio direction finder will warn him of drift. The whole problem of navigation independent of weather conditions seems to have reached solution.

Other accessories, unheard of in 1915 are the Interphone, permitting communication between pilot and passenger; the dual control release which permits the instructor to cut out the pupil who has lost his head, or persists in taking charge at the wrong moment. Light engine starters are now commonly employed, allowing us to dispense with the clumsy methods of turning up with a propeller; carburetor stacks and screens have minimized the danger of fire, fire-proof fabrics and dopes are certainly with us.

Materials have been the subject of constant study and cotton is again in the field, this time displacing linen not because of cheapness, but because of cheapness combined with qualities of strength and durability. Dopes are no longer to be feared as violent poisons, and where dangerous dopes are still employed, perfect systems of ventilation are in use.

Veneer has, due to its superior homogeneity of structural strength, come into its own, and found a large utilization not only in the fuselage and ribs, but in struts, spars and almost all parts of the airplane.

Built-up spars are no longer barred by specifications. Airplane constructors know how to make them, of equal strength and sometimes lesser weight than solid spars, thereby saving in the actual stock used, and in the rejections.

Struts are no longer made exclusively of spruce, we can turn to steel and while not cutting down weight can use smaller thicknesses and cut down head resistance. Steel spars are a decided possibility.

Engines have steadily grown in power and decreased in weight per horse-power, until 2 lb. per horse-power is commonplace and 750 horse-power in one unit employable. The air cooled engine has come to stay, lighter, more simple than the water-cooled type, and slowly gaining an equal reputation for reliability.

While trussing systems have remained more or less the same, construction of wings has improved. Streamline wire has been brought to the point where it may be used with safety.

Finally, in aerodynamics, better wing sections and finer bodies have been gradually evolved.

And as a result of all these improvements the airplane as a whole has, without any startling innovations, improved immensely in every way.

The war at least gave aeronautics a marvellous swing and impetus, and if but a part of this swing and impetus is maintained we may surely expect even greater things in the near future.

Aerial Competitions

With the advent of peace and the release of planes for civilian aviation it is to be expected that there will be a resumption of so-called aerial Derbys and competition of varying character. It is hoped that these will be run on a reasonable basis and not purely as a sporting or advertising proposition.

While great speed and climb will always be desirable factors in aviation, for commercial work other factors have an even greater importance. It is in the demonstration of these factors that aerial competition will be most useful.

They can be made to determine the durability of both engine and plane by long non-stop flights. Even if a plane has achieved a given distance in a given time in a competition, it should be penalized for any forced landings.

The useful load transported aside from fuel should be an important criterion, while the ratio of ton-miles to fuel consumed, being a measure of economy, should also be taken into account accordingly.

Our Third Anniversary

With the present issue AVIATION AND AERONAUTICAL ENGINEERING celebrates its third anniversary, entering upon its fourth year of existence. In this connection it may be recalled that this magazine was the first aeronautical publication in the world to realize the predominant importance of scientific research and strict engineering methods in the planning, designing and construction of aircraft; and, founded on this assumption which the experience of the Great War has strikingly vindicated, AVIATION AND AERONAUTICAL ENGINEERING has ever since its first issue considered it its principal duty to spread the knowledge of sound methods of aeronautical engineering.

What measure of success has been achieved in this endeavor, numbers of readers have kindly expressed in a large correspondence bearing congratulations and good wishes for the future. Some striking excerpts from such expressions of good will—which afford a powerful incentive to further improve the constructive features of AVIATION AND AERONAUTICAL ENGINEERING—are printed herewith together with suggestions regarding the development of peace-time aeronautics.

Champion of Progressive Movements

"AVIATION AND AERONAUTICAL ENGINEERING has, since its beginning, championed all progressive aeronautic movements. It has been one of the leaders in the demand for landing fields and favorable legislation. It has aided greatly in the education of the public as to the safety of travel by air."

GLENN H. CURTISS.

Progressive and Constructive

"I have always considered AVIATION AND AERONAUTICAL ENGINEERING to be one of the most progressive and constructive aeronautical magazines and am sure that this opinion is concurred in by the whole Air Service. Its articles have been devoted to the best interest and sound progression of aeronautics, and the part taken by this magazine during the past three years in dispensing up-to-date aeronautical engineering facts has made it a very valuable medium for the instruction of its readers along technical lines connected with aviation."

MAJ.-GEN. CHARLES T. MENOHER, U. S. A.
Director of Air Service.

Splendid Work

"I have been reading with much pleasure the valuable information contained in AVIATION AND AERONAUTICAL ENGINEERING from month to month, and congratulate you upon the splendid work you have done along this line."

BRIG.-GEN. WM. MITCHELL, U. S. A.
Director of Military Aeronautics.

Timely Symposium

It is wise to consider at intervals the general trend of aircraft design and development, and for AVIATION AND AERONAUTICAL ENGINEERING to hold a symposium on this subject now is especially timely. Your paper represents American thought in Aeronautical Engineering, and is in a position to assist in directing it into safe channels.

It appears to me that the naval development of aircraft will continue along its present lines, both heavier and lighter-than-air, and including all useful types for special functions. We will, therefore, continue to experiment with the very small and the very large. The future should give us machines both larger than any we have now and also smaller.

Flying boats are the backbone of naval aircraft, and are also the most promising type for commercial application. I wish it were appreciated in quarters now given to excessive enthusiasm that very large airplanes, while practical enough in the air, are as yet unable to make safe landings except on very perfect fields, level, large, and of smooth, hard surface. The size of flying boats is not limited by landing considerations. Indeed, the NC type has shown that in doubling the size of the F-5 type a landing speed 10 m.p.h. in excess of the safe landing speed for the F-5 is quite practicable. It is likely that still higher landing speeds, in excess of 70 miles, will be suitable for even larger boats. The above speeds are for use in harbors or sheltered waters and are the maxima. However, all the harbors, bays and rivers of the world may be considered landing fields, and the ocean itself, except in a gale, is a safer place to land than an ordinary meadow is for a large land plane.

Express and mail routes involving over-water transportation can best compete with rail transportation. When high winds and gales are to be expected, and for distances under 1000 miles, the flying boat seems most suitable. When fogs are to be feared and for distances over 1000 miles, airships are better adapted for service.

The airship requires a large investment for berthing space, and in the beginning will prove expensive unless the volume of traffic is great enough to carry the overhead.

REAR-ADM. D. W. TAYLOR,
Chief Constructor, U. S. N.

Admiration and Respect

"It is a pleasure to be able to congratulate you on the completion of your third year of an active and useful life, and to felicitate you on the accomplishments of that period. Your publication enjoys the admiration and respect of the aeronautical fraternity and in aeronautical development has been an instrument of much value.

"I hope sincerely the next three years will witness as great a development in aviation, under the happier auspices of peace, as the past three have, though this is probably too much to expect. No one who gives thought to the upward struggle of man, however, can doubt that from now on the fact he has conquered the air is going to be of ever greater significance in this struggle. I would not dare to be so unwise as to specify just what I believe will be the development in aeronautics, or when it will come, but it is certain that the ability to fly marks such an advance over man's previous condition that he will not fail to take full advantage of it. This may be delayed somewhat but it will come. In man's upward climb no such increase in his prerogatives has ever failed to be utilized, eventually, to the full, and in aeronautics the same result will follow.

"Unless the Government departments give the fullest financial support to aeronautics, progress will be slow, though it will be none the less sure. I do not see how the Government can fail in this particular, however, and look to a sound Government encouragement which will make possible a sound commercial development, from which the industry will eventually find itself so far as commercial uses are concerned. Lighter-than-air and heavier-than-air craft both have their uses and will develop side by side.

"In walking hand in hand with the future of aeronautics, AVIATION AND AERONAUTICAL ENGINEERING will have the best wishes of all who are interested in a sound, logical development."

COMDR. G. C. WESTERVELT, (C. C.) U. S. N.
Superintending Constructor of Aircraft, U. S. N.

Responsibility to Discharge

"As to the development of heavier-than-air craft, I have a conviction that designing engineers must learn something more than they now claim to in order to make passengers more independent of the pilot. Even a slight error in judgment on the part of the pilot may result in disaster to himself and all his passengers. This condition is not found in other means of transportation to so pronounced a degree. I offer no suggestion, because since entering the aircraft manufacturing industry I have been engaged as a manufacturer and not as an engineer.

"The development of heavier-than-air craft in the military world will be along new lines, especially in the Navy. During the Great War the Navy used heavier-than-air craft almost solely for anti-submarine work, and they must be developed for scouting, fire control and courier service.

"The development of lighter-than-air craft has only begun. The United States is actually at the beginning point, but, with its advantage of a supply of helium at least sufficient for its military needs, it ought by careful application of the funds made available for the art make a most substantial advance, and I believe I see more all-around usefulness for the lighter-than-air machine than for the heavier-than-air machine.

"AVIATION AND AERONAUTICAL ENGINEERING has a responsibility to discharge in this development brought on itself by the reputation it has gained for carefully reporting all progress and offering well considered papers and its own thoughtful judgment."

COMDR. F. G. COBURN, (C. C.) U. S. N.
Manager Naval Aircraft Factory

Scientific Success

"Congratulating AVIATION AND AERONAUTICAL ENGINEERING on the success it has achieved along scientific lines in its first three years of existence, we trust that its future will be even more prosperous than its past. Best wishes."

GREELY S. CURTIS.
Treasurer, The Burgess Co.

High-Class Technical Aspect

"In the future of aviation there is still great need for sound engineering development, particularly in the development of less expensive motors and in the further simplification of airplane construction.

"We already find high speeds of 160 miles an hour quite practical. What other means of transportation in as young a state as aviation can offer any such speed? Even though landing fields are a limiting factor, granting that there is an element of uncertainty and of high expense in air travel, if we can offer sufficient speed in travel from office door to office door, the world will be willing to pay a high price and to stand for a lot of bother because in speed of travel and in its unequaled directness of travel the airplane offers something of real practical use.

"Those who, realizing the present limitations of flying, begin now to build up a sound and solid industry, based on offering the public that pays for it something of real value in quick transportation, are going to be the pioneers of a transportation field offering as much in greatness as did the railroads a hundred years ago.

"It is a great pleasure to be offered an opportunity to congratulate AVIATION AND AERONAUTICAL ENGINEERING on the completion of its third year. Its efforts and functions in the industry have been peculiarly beneficial, particularly because of the high-class technical aspect of the magazine, which has been constantly kept up from its inception.

"The general run of aviation magazines that deal with newsy items lose in permanent value the temporary gain that they appear to have due to their timeliness. But the bound copies of a magazine such as AVIATION AND AERONAUTICAL ENGINEERING, with technical articles of real value, are a necessary addition to an aeronautical library."

GROVER C. LOENING.
President, Loening Engineering Corp.

Measure of Present Opportunity

There are great possibilities ahead for airship transportation in both governmental and civil lines; but to realize either in full we must have both. To support the Government quickly and effectively in time of war, we need an airship industry in this country, but this cannot be attained by merely building ships on Government order, for there will never be enough ordered in times of peace. The Government can, however, encourage commercial development in various ways and control it to the extent of making commercial ships available for military or naval use when needed. The nation will save in taxes, and at the same time get the benefit of bigger and better airships, lower fares and adequate military protection.

A large share of this development lies in your hands, AVIATION. The friends you have made in the past are a measure of your present opportunity, which is great indeed.

R. H. UPSON.
The Goodyear Tire & Rubber Co.

From the Ace of Aces

"Furthering the interests of AVIATION AND AERONAUTICAL ENGINEERING means to further the interests of its readers—and the lovers of aviation are indeed fortunate to have available a publication of such merit."

CAPT. E. V. RICKENBACKER.
Former Commander, 94th Pursuit Squadron, A. S.

Forcing Its Way Up

"AVIATION AND AERONAUTICAL ENGINEERING is to be congratulated upon the record which it has made in the crowded three years since its birth. I cannot think of any other case of a new trade magazine forcing its way into the front within a few months after its inauguration. I have no suggestion to make other than keep it up."

ARCHIBALD BLACK.
Aeronautical Mechanical Engineer, U. S. Navy Department.

A Power Since Its Beginning

I thoroughly believe in the future, and near future, of real aircraft activity. The number of actual sales of planes during the last four months is a real surprise.

I believe this future will come through industrial development of commercial type machines, and not from military activities or requirements.

Future planes will be safe in proportion as they forget military practice and design for new fundamentals. New engines, cheaper, more reliable, more compact, will come, and soon. Present types are too expensive and nervous, too delicate and temperamental. These engines will form the crux of the new developments, and will be the branch which commercially for a time will make the most money for the makers.

We must see airplanes of 150-mile cruising speed before we can really do commercial long-distance work. This means the elimination in some way of all parasite resistance, and more stable wing curves.

America should at once pay more attention to the airship of large size—a million cubic feet and over. It is possible to build these in the newer plywood constructions rather than of aluminum, and in the giant sizes the entire envelope can be of this non-electric and reliable material.

A government-held contest for commercial planes for various uses held each year would greatly stimulate development, and forestall charges of political preferences in contracts which the public and press are always too apt to bring.

AVIATION AND AERONAUTICAL ENGINEERING has been a power since its beginnings, and is a wholesome note, edited for the industry and not for one man's personal publicity. More power to it. Why cannot some American paper assume authority as the British papers do? I believe your paper has brains enough to do it. They never call a spade a shovel.

WM. B. STOUT.

Educate the Public

"Soberminded men do not believe war is eternally ended by certain signatures on scraps of paper any more than they believe crime is to be abolished by formal passage of laws. A nation is always in the same peril of war as is an individual in danger from criminals. We have just learned a costly lesson in unpreparedness. In piping times of peace we should prepare our aviators for war.

"The United States lags behind in this program of preparedness—preparedness both against possible assault and, more important still, preparedness to take her place in the rivalry for commercial aviation that is now upon us. A new science of transportation is awaiting our development. What impetus is needed to get us under way?

"Public familiarity with the advantages of aviation is the answer. Aviation magazines should keep the public fully and correctly informed of the possibilities of aviation. The quantity of misinformation that goes forth unblushingly from our sensational presses must be checked and censored at its source by educating the press in the science of aviation. The "safety-first" of aviation must be emphasized rather than the death-defying stunts of the hair-brained aviator.

"To this end AVIATION AND AERONAUTICAL ENGINEERING stands preeminent above other publications of this country."

LAURENCE LA TOURETTE DRIGGS.
President American Flying Club.

In a Class by Itself

"AVIATION, as we engineers familiarly call it, is in a class by itself, being the truly real technical publication of the industry. While the other aeronautical magazines give the news of general interest, pictures and a few of the more or less technical articles, AVIATION is the one that the aeronautical engineer wants on his deck at his elbow.

"As to the prospective development of aircraft for governmental and civil purposes, it is the writer's opinion that there is still a great deal to be done. The tendency at present seems to be to design large machines both for bombing and commercial work. By drawing a comparison between the trans-Atlantic flights of the Vickers "Vimy" and the R-34, the importance of the heavier-than-air craft is at once apparent. Although the former is not as large as successful planes already constructed and its useful load is small in comparison to that of the R-34, the fact that its time of flight was one-fourth that of the airship proves its supremacy. The distinctive advantage of the heavier-than-air craft upon the ground argues well for the intense development of the large load carrying airplane. Vastly larger planes than the Vickers "Vimy", with useful loads many times greater and capable of attaining airspeeds of over 100 m.p.h. will, with the proper support, be developed within a short time for trans-ocean carrying.

"Without doubt a number of very good one and two passenger planes for military and sport purposes will be developed far exceeding in performance those with which we are now familiar. These types should be always kept at the highest point of development as a very important measure of preparedness.

"But it is not possible for the aircraft manufacturers to accomplish all this single handed. Until the industry is upon a settled peace basis it will be neccssary for the manufacturers to have outside assistance. The logical point from which this should come is the Government and yet it remains to be seen whether the United States is to maintain her place in the sun."

GLENN D. MITCHELL.
Chief Engineer, L-W-F Engineering Co.

Positive Engineering Authority

"The development of aviation in the United States has been largely dependent upon the support of the Government in recent years, but now that Congress has made only a small appropriation for the coming year I feel that we must and can justly expect the public in general to take a large part in future development.

"With the crossing of the Atlantic came a new era in commercial aviation. It has proven to the public, beyond doubt, the wonderful possibilities of aviation for rapid transportation. The performance of the Air Mail Service during the past year is doing much to drive home the reliability of the airplane and its cheapness of operation.

"Landing fields should be established throughout the United States, starting with such well traversed routes as between the principal Eastern cities, New York to Chicago, etc. These fields should be at intervals of fifty miles so that a safe and sure landing can be made at any point. A small aerial garage should be a profitable enterprise at each station and one that would be taken over by mechanics trained in the proper care and upkeep of all types of aircraft and engines. With fields of this kind commercial aviation will come into its own very soon.

"The public must be continually brought to see the possibilities of this new mode of transportation. Large regular passenger planes will come into use. These should be equipped with several engines, so that a constant flight can always be maintained from city to city without a forced landing due to engine trouble. The comfort of the passengers must be carefully taken into consideration, also enough storage to allow for light baggage. Each engine should be accessible while in flight, that minor repairs may be made without landing.

"During the three years of its publication AVIATION AND AERONAUTICAL ENGINEERING has contributed much to the development of aeronautics in this country by the comprehensive way in which it has handled various problems.

"We have found no other magazine that is so complete and broad in its setting forth the aeronautical data that is of equal value to the average layman and yet a positive authority for the aeronautical engineer. You should be justly proud of its work."

B. RUSSEL SHAW.
General Manager, Aeronautical Instruments Corp.

The Need of the Present Moment

By Archibald Black
Aeronautical Mechanical Engineer, U. S. Navy Department

Practically nine months have now passed since the signing of the armistice and—to say the least—conditions in the aircraft business in the United States are anything but encouraging. Two of our largest manufacturers have wound up their affairs and those remaining are struggling along with, in most cases, practically no business on hand.

Barring unexpected developments it does not appear likely that U. S. Government orders for aircraft for military or naval purposes can be counted on for twelve months or more. If we are to continue selling airplanes or other aircraft for war purposes we will have to look for foreign outlets. The South American nations and probably also China and Japan are likely to come into the market for more or less limited numbers of machines similar to some of those which we have been building. The amount of this business and when it will materialize are, however, very problematical. While some orders will probably be placed by the Post Office Department this year these will, in any case, not be sufficient to do more than keep one or two of our plants operating on a limited scale.

The sporting and commercial business is our "dark horse." Since Nov. 11 last, the country has been busy starting the wheels of industry turning in a reverse direction with the result that few have had time to look around for new forms of sport or new lines of investment. Naturally the first impulse of the discharged man, be he officer or private, is to get back at the wheel of his business or to buckle down to his former work as the case may be. He finds a thousand and one home and business affairs awaiting his attention and any thoughts which he might turn to the conquest of the air have, perforce, to be laid aside for another day.

We are already well under way towards normal conditions and it seems likely that next Spring may show some call for sporting airplanes as the flying fever contracted in the Air Service begins to reawaken. In the meantime, it behooves each manufacturer to see that no time is lost which could be spent in organizing flying fields throughout the country, for the necessary legislation for control of aircraft and carrying on an educational campaign to remove from the public mind some of the erroneous and ridiculous ideas about aircraft which are still prevalent.

A national body having for its object the organizing of flying fields, in cooperation with the Army, Navy, Post Office, municipalities and other local bodies, would be of very great value at this time. The level-headed men comprising the Manufacturers' Aircraft Association are, in the opinion of the writer, the best fitted to start the ball a-rolling in this direction. Without chains of flying fields, or at least emergency landing fields, covering the entire country, any attempt to develop the sporting end of the business will prove to be very uphill work.

The operation of experimental passenger-carrying lines is a phase which calls for the earliest attention and could be started by individual manufacturers or by them in a body through a corporation organized for this purpose. There are many places where local transportation conditions are such that airplanes and airships *designed for the purpose* could very likely be operated at a reasonable profit. It appears essential however, that the matter be handled in a conservative and business-like manner, holding in mind the fact that one fatal accident could set the business back a few years.

To sum up I might make the following suggestions to manufacturers: (1) Organize chains of flying and emergency landing fields to cover the entire country. (2) Put into operation, as soon as possible, specially designed passenger and express carrying aircraft, choosing routes to which this service is particularly adapted. (3) Prepare attractive, airworthy and inexpensive sporting designs in time for next spring and summer. (4) *Don't build flying flivvers until the commercial lines are in operation.* The "flying flivver," in the hands of the public, is liable to prove the fool killer par excellence and create a grossly exaggerated idea of the dangers of flying.

The Future of Commercial Aviation

By Glenn H. Curtiss

The future of aviation, as it concerns land machines, depends upon one thing—the establishment of landing fields.

Regardless of the progress made in aeronautical design, the fact remains that aerial progress in land flying will not reach its maximum possibilities until the importance of the establishment of landing fields is fully realized.

It is really a remarkable thing how commercial aviation has progressed during the few months since the cessation of hostilities. It is doubly remarkable when you consider that this progress has gone on almost unaided. It has made wonderful strides—a remarkable chapter in the history of the world's industrial development. Such progress as has been made has been largely the result of individual far-sightedness, individual progressiveness, individual enterprise and initiative.

The railroad awaited the laying of rails, the automobile and motor truck awaited good roads, the airplane awaited nothing. It has gone ahead without waiting for the developments that should accompany it.

It has gone about as far as it can without any aid in the way of landing fields, service stations, weather reports and meteorological reports. Some progress has been made, and we are now finding cities awakening to their opportunities.

Landing fields mean safety in flying; safety in flying means greater education of the public to the enjoyments of flying; education means progress. One follows the other.

Some time ago I made the statement that the greatest progress in aviation would be made by water machines because of the fact that water machines have natural landing fields. The trans-Atlantic crossing was a great boon to water-flying, but just as soon as we have established a system of landing fields we will accomplish feats equally as important with land machines.

There is a wide field for the airplane. It may be safely said to have already taken its place in the world's commercial service. Experiments carried on by the Government in aerial mail, aerial photography, aerial mapping and forest patrol have already proved their usefulness. Its worth in emergencies has been proven time and again. The commercial tests to which they have been put have been in almost every case successful and beneficial.

It is hard to realize that within the last few months airplane designers have succeeded in making the transition from war to peace-time vehicles; that mercantile establishments are using the airplane to make deliveries; that physicians are flying to make their calls; that accessories are being delivered by air; that aerial police corps are being organized; that hotels are establishing aerial services; that there is a greater demand for aerial exhibitions than there are pilots and planes to fulfill; that fliers are finding profitable employment in passenger-carrying; that papers are using airplanes to deliver newspapers and photographs; that the airplane is being used in ambulance work.

The developments have been rapid, but the coming year will see still greater progress. How much this progress will advance will depend upon the co-operation given this new industry.

Development of Aircraft for Governmental and Civil Purposes

By Maj.-Gen. Charles T. Menoher, U. S. A.

Director of Air Service

The development of aircraft for commercial purposes and for peace time Governmental activities has hardly begun. The enormous advance made in aeronautics during the last five years has been due to the necessities of war and as a result the the aircraft of today is suitable for war rather than for commerce.

Speed, climbing ability and visibility for pilots and observers are the chief requisites of military aircraft. These qualities are so essential that they have been developed at the expense of almost every other consideration. Operating costs and production costs were hardly considered. Maneuverability was desired rather than inherent stability. In fact, the lines of development dictated by the necessities of war lead away from commercial success rather than toward it. The knowledge and experience gained in the production of present types, however, is so great that aeronautical engineers should be able to produce aircraft capable of almost any desired performance.

An intelligent analysis of commercial possibilities of aircraft is necessary. Every venture should be carefully studied to determine the requirements of the aircraft to be used, and a special ship designed to meet them. Present effort seems to tend too much toward the adaption of present types rather than a design of new types better suited for specific commercial purposes. The attempt to find peace times uses for material designed purely for war has resulted in many ill conceived ventures doomed to certain failure. Legitimate possibilities exist before it takes its proper place as a mode of transportation in plenty, but before commercial aeronautics is a success and and communication, much careful planning and skillful design will be necessary. Every development in transportation has been toward increased speed and the saving of time. All have met and overcome opposition based on increased cost of operation and danger. A long and painful course of education of business to the possibilities of each has been proved necessary. Doubtless the advent of aeronautics will prove no exception. The exigencies of war, however, have presented to business a new and improved method of transportation ready made. All the knowledge and experience necessary to put it into effect are at hand and it remains only for business to realize its possibilities and limitations, and to take immediate and profitable advantage of it.

Transportation by aircraft is the most rapid method known and, measured by "pounds per hour," probably the most expensive; yet there is business in plenty important enough to justify the added expense of saving a few hours. Aircraft can compete along its own route with every known method of transportation, from the burro clambering over the Rocky Mountain trail to the fastest steam railway or the ocean going steamer. With every reduction in production or in operating costs, an ever increasing amount of profitable business becomes available.

A business concern or a nation that depends upon obsolete transportation methods is doomed to commercial failure. England, France, Italy and Japan are bending every energy to the development of aircraft for commerce. Germany waits only for the word of release to become a formidable competitor of the most progressive nation. Only the United States lags behind. If these nations find it necessary to give Governmental aid during the period of transition of military to civil aeronautics, we should profit by their example before it is too late. Otherwise we may find our most important lines of transportation in the hands of aliens. Our merchant marine should be warning enough.

Metal Construction of Aircraft*

By A. P. Thurston

With regard to metal construction of aircraft, it may be argued that metal is too heavy to be used to construct efficient flying machines. The same argument was used in the early days of iron vessels; now wood is used only to construct small craft, and all large vessels are constructed of steel. It will be shown later that steel and duralumin are stronger than wood, weight for weight, and that the vital members of our flying machines can be, and have been, made lighter and stronger in metal than in wood.

Heretofore, with a few notable exceptions, the vital members of the aircraft structure have been made of wood. The weight and strength of specimens from the same species differ greatly. Spars for one type of machine were found to vary in weight from 6½ lb. to 16 lb., and the strength varied in

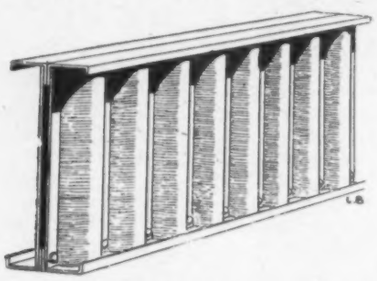


FIG. 1. STEEL AND ALUMINUM ALLOY SPAR FOR BE-2E AIRPLANE

practically the same proportion. In addition, the strength decreases with the amount of moisture absorbed. Thus, the strength of spruce in compression decreases 230 lb. per sq. in. per 1 per cent of moisture between 10 per cent and 25 per cent. moisture. Wooden machines sand tested under the very favorable conditions of a dry workshop therefore showed a much greater strength than in the field. A sodden machine in the tropics may have only half the strength of the same machine when tested in the workshop at home. Moreover, owing to the disposition of wood to warp or split, particularly under tropical conditions, a wooden machine quickly gets out of truth and requires trueing up. Wooden wings deflect a great deal under load, thus making it impossible to keep all portions at an efficient angle of incidence. For instance, in a single bay wooden machine under load it was found that the angle of incidence changed 1 deg. under the struts, while in the middle of the bay the angle of incidence changed 2½ per cent. As this machine flew with an angle of incidence of not more than 1 deg., it follows that some parts of the wing were lifting much more than other parts; moreover, the maximum loads were applied in the least favorable place—namely, in the middle of the bay. From these considerations it follows that there is a strong argument in favor of metal construction if it can be efficiently and cheaply utilized.

Basic Principles

The metals which are immediately available for metal construction are steel and duralumin; other alloys should be available shortly.

The specific gravity of good dry spruce, grade A	= .45.
The specific gravity of steel	= 7.8.
The specific gravity of duralumin	= 2.7.
Young's modulus in bending for all steels approx	= 13,600 tons sq. in.
Young's modulus in bending for duralumin approx	= 5,500 tons sq. in.
Young's modulus in bending for spruce, A approx	= 715 tons sq. in.

* Excerpt from a paper read before the Royal Aeronautical Society.

Hence, steel is 17 times heavier than good spruce, while duralumin is 6 times heavier than good spruce.

The strength of spruce in bending cannot be assumed greater than 5,500 lb. sq. in or 2.45 tons sq. in. Hence, steel of 42 tons per sq. in. or duralumin of 14.7 tons per sq. in. are equal in pure bending, weight for weight, to grade A spruce, providing the full strength of the material can be developed. The strength of a long strut or spar under combined bending and end load is governed by the modulus of elasticity. The strength of a long strut with free ends being given by Euler's formula $\pi^2 EI/l^2$. It follows that steel struts are, weight for weight, 1.1 times as strong as spruce, and that duralumin struts are 1.28 times as strong as spruce, provided the full strength of the metal is developed. These figures relate to the best wood obtainable under peace conditions, but they are much

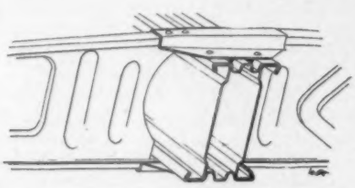


FIG. 2. SADDLE-PLATE METHOD OF JOINING RIB AND SPAR

more favorable to metal when compared with wood available under war conditions. Thus, the specific gravity of dry Oregon pine or Douglas spruce, which we have been compelled to use in large quantities, is 0.51. The transverse strength or bending strength of grade B timber is 4,500 lb. per sq. in. or 2 tons per sq. in. The modulus of elasticity of grade B timber is 625 tons per sq. in. Therefore steel is 15 times heavier than grade B Oregon pine, and duralumin is 5½ times heavier than grade B Oregon pine. Hence, steel of 30 tons per sq. in. or duralumin of 10½ tons per sq. in. are equal, weight for weight, in pure bending to grade B Oregon pine, provided the full strength of the material can be developed. Further, steel struts are, weight for weight, 1.4 times as strong as grade B Oregon pine, and duralumin struts are 1.6 times as strong as grade B Oregon pine. Moreover, since the deflection of a beam under load is proportional to the modulus of elasticity and the end load in a beam introduces an additional bending moment equal to the product of end load and deflection, it follows that the above figures are capable of being improved upon, provided always that such a design can be obtained and that the full strength of metal can be developed.

Metal construction has the further advantage that the metal may be disposed at a greater average distance from the neutral axis. It may be argued, since the modulus of elasticity of all grades of steel is approximately the same, that the grade of steel to be used in struts is of no importance. This is not so in fact, because with mild steels small local damage causes local failure, whereas with higher grade steel local damage is of minor importance.

Local Failure

The metal used in the construction of metal airplanes must be extremely thin if it is to compete in weight with wood. The most useful thicknesses for steel have been found to be .015 in., .018 in. and .022 in. Duralumin has the advantage over steel in that it is three times thicker, weight for weight. The chief difficulty with thin metal structures is local failure due to local flexure before the full strength of the material has been developed.

A preliminary series of tests were made by Major Wylie on square tubes having flat sides 1⅜ in. wide which were fifty times the thickness of the metal. The tube was heat treated so as to raise the elastic limit of the material to above 80 tons per sq. in., but when tested by bending the side in compression

formed transverse corrugations at a stress of 25 tons per sq. in., and these corrugations increased with increasing load, and finally caused failure at a stress of about 40 tons per sq. in. When tested in compression the tube failed completely at about 25 tons per sq. in. as soon as the corugations appeared. Further tests on circular tubes of the same thickness and of diameters varying from 1⅜ in. up to over 2 in. were also made, and in all cases the circular tubes developed the full strength of the material. A 1¾ in. × 22 gage tube did not collapse until a stress of over 110 tons per sq. in. had been reached, and then failed suddenly at a slight dent. A tube having a diameter of over 2 in. and a thickness of .01 of its diameter, which is considerably less than 22 gage, did not fail until a stress of 100 tons per sq. in. had been reached, and then failed in tension. It is evident, therefore, that curved surfaces must be used instead of flat surfaces. From tests which have been made it appears that the radius of curvature should never be more than twenty times the thickness of the metal. This is unlikely to put any limitation on good design and will insure the section standing up to the maximum strength of the material without failing, and make it capable of taking a fair amount of punishment from local damage.

Materials: Steel Strip

Thin steel strip is produced by cold rolling, as it is not economical to roll material in the hot state to less than 17 or 18 gage. The hot rolled strip is usually first pickled and then cold rolled to the thickness desired. As the metal is reduced in thickness it is hardened, and the tensile strength and yield point increased, and a point may be reached where the hardness is so great that it must be removed by annealing before further reduction can be made. With a .3 carbon steel a reduction of more than 40 per cent by cold rolling after annealing makes the strip too brittle. A 1 per cent carbon steel may be reduced to a quarter its thickness before annealing is necessary, whereas a .8 per cent carbon steel can only be given a slight reduction in thickness without annealing. This makes the process of cold rolling costly and laborious—.3 per cent to .4 per cent carbon steel appears therefore to be the most suitable quality in which to obtain large output with good strength. By cold rolling a .3 to .35 carbon steel the tensile strength and yield point may be increased up to about 65 tons per sq. in. with practically no ductility. This renders the strip unsuitable for rolling into suitable sections. If, however, the strip is tempered or "blued" for 15 to 20 min. at any temperature between 0 deg. and 450 deg. Cent., the ductility may be increased to any desired amount according to the temperature, and the maximum breaking stress and yield point do not fall to that of the original cold worked figures until a temperature of 425 deg. to 450 deg. Cent. is reached. Usually blueing for 20 min. at 400 deg. to 450 deg. can be relied on to increase the ultimate and yield strength by 5 tons per sq. in. and the elongation from practically nothing to about 7 per cent. This is a remarkable property of steel which was first discovered in connection with tubes and afterward applied to steel strip.

One process of manufacture consists in cold rolling and blueing simple carbon steels. The process of rolling develops a grain in the material which cannot be removed even by complete annealing; steel strip is therefore unsuitable for bending or rolling into sharp angles, and all strip steel designs should be formed of easy and continuous curves or corrugations. This is a second reason for longitudinal corrugations in design.

A second process of manufacturing steel strip is by continuous quenching and annealing low and medium carbon steel strip. The response to this form of heat treatment is very much greater in thin strip than in ordinary sections. There are several modifications of this process. In one process the steel strip passes continuously through a furnace and the red hot strip is quenched by running through an oil bath. The quenched strip then runs through a lead bath and is tempered. In another process it is quenched by running between cast iron or steel dies through which water is circulating and is afterward tempered in a gas furnace. In both the oil quenching and lead tempering process and the die hardening and gas tempering process care must be taken to cool the strip after being tempered before winding on a coil, otherwise the heat accumulated and the strength and ductility of the strip at different ends of the coil vary considerably. Some of the best results have been obtained with rejected corset steel. A coil of steel containing about .32 per cent carbon, oil quenched, hardened outright and tempered at 200 deg. Cent., had a strength of 115 tons per sq. in. with quite moderately good ductility, while after tempering at 250 deg. the strength was 110 tons per sq. in., the yield 90 tons per sq. in., and the ductility was sufficient when bent along the grain to enable it to be rolled into a standard corrugated flange. Further tempering of this same strip at 450 deg. Cent. reduced the strength to about 70 tons ultimate and 65 tons yield, and induced sufficient ductility in the material to enable it to be flattened on itself either way of the grain, so that this metal was quite capable of withstanding being pressed into ribs.

The third process, which has yielded excellent results, consists in hardening and tempering by a special process alloy steel strip. The resulting product is scoured by a special process and can be welded, punched, rolled and bent longitudinally and laterally without further heat treatment. This steel should be tempered either below 150 deg. Cent. or above 450 deg. Cent. if durability and capacity to resist shock and vibration are required.

The strength of metal constructions appears to be governed more by the yield point than by the ultimate strength, hence attention should be paid to obtaining a good yield point. Straight steel strip can now be obtained up to 5 in. wide, having yield points of 100 tons, 80 tons, 60 tons, or 40 tons. In ordering strip care should be taken to order the exact width required, since the process of splitting the strip invariably gives it a curve which can only be corrected by additional heat treatment.

Duralumin: Comparisons with Steel

The second material available for metal construction is duralumin. This has many advantages over steel and a few disadvantages. Duralumin being three times lighter than steel, it follows that the various members may be, weight for weight, three times thicker than steel members. Hence the difficulty in overcoming local failure due to local flexure is greatly reduced. Nevertheless, the perfection of a design can only be discovered by constructing it in steel, and it is thought that duralumin designs will be improved by adopting the principles which have proved to be the only feasible ones in steel construction.

A prejudice appears to exist in certain quarters against duralumin owing to the fear of corrosion. It should be stated that duralumin, unlike aluminum, is not acted upon by sea water or affected by atmospheric influences, and experience in connection with airship work shows that duralumin, if properly varnished, is not affected by corrosion under ordinary conditions of service. Nearly every case of corrosion so far experienced in actual practice has been traced back to incorrect heat treatment or to cold working after heat treatment. The heat treatment of duralumin instead of being a disadvantage, as is often supposed, is in actual point of fact of the greatest assistance in the practical working of the metal. This heat treatment is carried out by placing the members to be treated in a bath containing a mixture of potassium and sodium nitrates heated to a temperature of 480 deg. Cent. In practice there is a fairly wide margin of temperature so long as 500 deg. Cent. is not exceeded, in which case there is danger of the metal being burned and reduced to aluminum. The parts should be left in the bath long enough to be heated uniformly to the temperature of the bath, the actual times allowed being five minutes in the case of small units up to several hours in the case of 3 in. bar. There is no danger in leaving it in the bath too long, providing the actual temperature of 500 deg. is not exceeded. At the end of this time the article is removed from the bath and quenched out in water or non-acid oil. Immediately after heat treatment the metal is found to be in a very soft and plastic condition, and it may be pressed, forged, bent to the smallest radius, or in the case of drawn sections which have warped with the quenching, straightened without any fear of damaging the metal. The metal now commences of itself to harden up, and in about an hour's time has reached about 26 tons tensile strength, with an elongation of about 15 per cent. This process of hardening continues for a very long period, the strength slightly increasing at the expense of the elongation. Heating duralumin to 300 deg. Cent. and then quenching out anneals the metal, and it can then be worked in any way desired. In order to give it back its strength it is necessary to heat treat it at 480 deg. Cent., as explained above. In practice it is usual to anneal any duralumin part if a num-

ber of operations have to be performed, and, on the other hand, to heat treat before final operation if this is not of too prolonged a nature, taking advantage of its abnormal condition immediately after heat treatment. An actual example of the value of this property of duralumin in slowly hardening up after heat treatment occurs when duralumin is used for rivets. If an attempt were made to rivet these up in the ordinary hard condition they would crack badly. By heat treating them, however, and using them immediately after this, a perfect job may be made while they are soft, and within a very short time afterwards they have hardened up to their full strength.

If duralumin in the ordinary hard condition is bent to a small radius, there is, as would be expected, a probability of incipient cracks developing on the surface of the metal at the bend. These cracks are the places where the corrosion begins. If the metal was properly heat treated before such bending no injury would be caused to the surface of the metal, and no trouble would be experienced from corrosion. Nearly the whole of the prejudice against the use of duralumin is due to ignorance as to its properties with and without heat treatment. Sections cannot conveniently be drawn thicker than .2 in. Above this thickness the sections are extruded. It is advisable to use only solid drawn sections for the constructional purposes, and designs should accordingly be modified to meet the limitations in the material.

Design and Calculation of Guide Spars

In designing the most economical braced girder to withstand a certain definite system of loading, there are usually three points which have to be considered if the highest efficiency is to be obtained. These are: (*a*) The ratio of the over-all depth of the guide compared with its pin-jointed length. If the guide is made very deep the weight of the bracing becomes excessive, while, on the other hand, if made too shallow, unnecessary weight has to be put into the main flanges or members. The maximum depth of the girder is usually limited by the section of the plane. (*b*) The pitch of the bracing. If this is too great, unnecessary weight has to be put into the main flanges. If the pitch is too small the weight of the bracing is unnecessarily heavy. (*c*) The properties of the actual section used for the main flanges or members. If the member is made very thin it fails at a low stress by secondary flexure, while, on the other hand, if the flanges are made very thick compared with their width, the radius of gyration for a given sectional area is necessarily small in proportion to the pin-jointed length, that is, to the pitch of the bracing, and hence the member also fails at a low stress. The effect of varying each of the above items has been very carefully investigated and general data obtained which enables not only the strength of any particular girder to be accurately calculated, but also the girder to be so proportioned as to allow the maximum efficiency, from the point of view of strength for weight, to be obtained. In addition to the above three points there is an additional one (*d*), which has been investigated and has been found may be neglected. At first when the subject was approached it was thought that the strength of the small elements between points of attachment of adjacent bracing would depend on the stiffness of the bracing. Experiment has proved that the increase of strength to be obtained by this means unnecessarily increases the weight of the bracing and is not economical, and that the strength of the individual main member or flange may be calculated, by confidential information memoranda 720, as a strut with pivoted ends and of a length equal to that between the centers of the bracing attachment. If the bracing were infinitely stiff and were attached to the main member in an absolutely rigid manner, the pin-jointed length of the elementary strut would be half the pitch of the bracing; on the other hand, if the bracing is without stiffness, or if only attached by a single rivet to the main member, then the pin-jointed length is taken as equal to the pitch of the bracing. The exact effect of the stiffness of the bracing on the pin-jointed length of the main member can be actually calculated in any case. C I M. 720 has been brought up to date and amplified by a large number of experiments on flanges of various thicknesses.

Having fixed on the dimensions in (*a*), (*b*) and (*c*) above the strength of the girder as a whole is next considered. The strength of the individual member, usually the flange between points of support of the bracing, is taken as the limiting stress at the center of the girder, and then the failing load at the ends of the girder is calculated by the Alexander strut formula, which has been proved to give results in agreement with experiments. The Alexander strut formula is as follows:

$$\frac{l^1}{k^1} - \frac{l}{k} = A\frac{\delta}{k} \times \frac{\sqrt{p}}{f - p}$$

where p is the intensity of stress in tons per sq. in. on the ends of the strut at failure.

f is the limiting fiber stress at the center of the strut at failure. It is approximately equal to the limiting fiber stress under conditions of pure bending.

$\frac{l^1}{k^1}$ is equal to $\pi\sqrt{E/p}$. If Euler's curve for the material is plotted—that is, $p = \pi^2 E/(l/k)^2$ then l_1/k_1 is equal to the horizontal distance out to this curve at a height corresponding to the failing pressure p.

$\frac{\delta}{k}$ is the ratio of the distance of the extreme fiber from the neutral axis, to the minimum radius of gyration, measured in the direction of the latter.

A is a constant which equals $2c\sqrt{E}$ where c is the ratio of the equivalent eccentricity to the radius of gyration, usually taken as 1/10 for ordinary struts and 1/20 for especially straight struts. The value of $A = 2c\sqrt{E}$ is found by experiment for duralumin braced girders to be about 10.

The thinner the flanges of the angle, that is, the higher the value of s/t, where s equals the thickness of the flange, and t equals the width, the lower is the limiting stress at failure at the center of the strut. This reduction in the limiting stress in the thinner members is, of course, due to the effects of failure by secondary flexure. By plotting the failing loads of a series of experimental beams having varied thickness of angles against s/t for the angles, a simple investigation shows the most efficient value of s/t to use with a fixed pitch of bracing. With plain angles the limiting stress for sections for which $s/t = 30$ is only 7.8 tons per sq. in. On the other hand, for values of $s/t = 7$ the limiting stress is 17.5 tons per sq. in. The most economical values of s/t for plain angles appear to be between 6 and 8, and in any case should not exceed 10.

In general it was found that lipping improves the thin section, while on the other hand the failing stress in the case of the thicker sections is only a little higher. For instance, the limiting stress for sections for which $s/t = 30$ is 11.7 tons per sq. in. as against 7.8 for plain angles, whereas for values of s/t of 7 the limiting stress of the lipped section is only 17.5—*i. e.*, the same as the plain section. Hence there appears to be no advantage in lipping the sections.

Conditions of Economical Design

In order to obtain the most economical design, it is obvious that the dimensions of the main members will require to be varied from place to place. Therefore at the center of a large machine, in view of the fact that duralumin cannot efficiently be solid drawn in sections thicker than 0.2 in., it may be found that the size of the angle members required become too great to permit them to be solid drawn. It therefore becomes necessary to modify the design. In one such modification plain angles are used to which are riveted longitudinally corrugated plates. To prevent local buckling of the plates the pitch of the rivets should not exceed 15 times the thickness of the plate. With regard to bracing it has been found that the best type of bracing is quite different to that used in airship girders. In the case of airships, since the shear is small, and the main members are of light section, with a large pitch for the bracing, it follows that a rigid bracing in the plane of the members is economical. Moreover, discontinuous bracing gives a further economy.

In the case of airplane girders the main timbers are much heavier and the value of L/K between bracing points so much smaller that the increase of strength to be gained by providing stiffening bracing is not justified. Moreover, since the shear is large it follows that the bracing should be practically continuous to obviate the introduction of local bending moment; further, the Zeppelin type of bracing is inadmissible, as this would necessitate double bracing. The problem of the suitable attachment of the fittings presents as great difficulty in the case of large machines as in small ones. It is of such importance that the design should be modified in the first instance to

enable this to be done economically. In calculating the strength of a spar it is necessary to make allowance for the extra stresses induced by the bending moment introduced by deflection. For wooden spars it is usual to use Perry's formula for a strut subjugated to a bending moment. The bending moment due to the lateral load is then multiplied by $Pe/Pe - P$ to obtain the equivalent bending moment. Where Pe = Euler's crippling load and P = end load in lb. This makes allowance for the additional stresses placed upon the spar due to the bending moment obtained by the product of end load times the deflection, and gives the fairly satisfactory results for spindled wooden spars. It cannot be used, however, for calculating the strength of metal construction, experiment having proved that the deflection is of the order 10 times that given by Perry's formula. The deflection of metal spars calculated in the following way has been found by Mr. Temple to agree with practice. From the ordinary theory of beams the deflection in the center of a girder under side loading is equal to

$$\delta = \frac{5\ L^2M}{48\ EI}$$

Where δ is the deflection in inches.
L is the length between the supports in inches.
M is the maximum bending moment in inches.
I is the moment of inertia in inch units about an axis perpendicular to the direction of loading.
E is Young's modulus for the material of the girder which as a result of bending tests on girders is taken as 5,500 tons per sq. in.

Since

$$\frac{M}{I} = \frac{2f}{L}$$

where f is the limiting fiber stress and D is the total depth of a symmetrical section we have

$$\delta = \frac{5}{48} \times \frac{L^2}{5{,}500} \times \frac{2f}{D} = \frac{1}{26{,}400}\ \frac{fL^2}{D}.$$

Now in the case of a long strut, if the direct stress is ignored, practically the same law should hold.

Since

$$M = Pe \times \delta \therefore Pe = \frac{M}{\delta}$$

but

$$Pe = \frac{\pi^2 EI}{L^2}$$

$$\therefore \frac{M}{\delta} = \frac{\pi^2 EI}{L^2}. \qquad \therefore \delta = \frac{ML^2}{\pi^2 EI}$$

but

$$\frac{M}{I} = \frac{2f}{D}. \qquad \therefore \delta = \frac{2L^2 f}{\pi^2 ED} = \frac{2}{9.87 \times 5{,}500}\ \frac{L^2 f}{D}$$

$$\therefore \delta = \frac{1}{27{,}100}\ \frac{fL^2}{D}$$

The deflections calculated by the above means agree with the results of experiments. Therefore, in designing beams to withstand combined stresses the approximate deflection should be calculated by the formula

$$\delta = \frac{1}{26{,}400}\ \frac{fL^2}{D}$$

Variety of Designs

In experimenting with metal construction one is impressed with the inconceivable number of designs which are possible. The most suitable design varies with each type of machine and the load which it is to carry. The duralumin designs previously shown are suitable for a large machine. In the case of machines of intermediate size— that is, the order of 10,000 to 12,500 lb., a suitable type of section is found to be one in which the main members are of channel section, which may be corrugated when necessary to reduce the effects of failure by secondary flexure. With thicker sections the central corrugations may be dispensed with. A spar of this type weighs only 75 per cent. of that of a corresponding spruce spar of the same strength.

In investigating the suitability of a construction to withstand the loads which are to be put upon it, care should be taken to reproduce as nearly as possible the conditions under which the specimen will be loaded in practice. Thus, the specimen should be subjected to the same bending moment and the end load as in practice. Reference has heretofore been made as to the serious errors which have been made in testing wooden specimens in pure bending instead of in combined bending and compression. The same errors may be made if the correct procedure is not followed in testing metal construction.

Prize for Trade Trips

The *Daily Express* offers a prize of $50,000 open to the world, with the exception of the late enemy countries, for an air flight establishing communication on a commercial basis with India and South Africa.

All competing machines must carry a useful cargo of at least one ton on outward and homeward flights. Factors in the award will be average reliability and airworthiness of machines.

American Handley Page Co.

The American Handley Page Co., with headquarters in Ogdensburg, N. Y., was incorporated June 17 " to establish airplane routes within the United States to carry passengers and merchandise," according to the certificate of incorporation filed at Albany. The capital stock is $5,000,000. The directors are: William H. Workman, New York; Harry Clark, Montreal, and Julius Frank, Smith L. Sawley, and Cecil Brownlow, all of Ogdensburg.

A Letter

Editor, AVIATION AND AERONAUTICAL ENGINEERING—In the June 15 issue of your valuable paper the article entitled " General Summary of the de Bothezat Blade-Screw Theory " by Professor George de Bothezat, has been the cause of considerable comment principally occasioned by its title. The theory of propeller action there presented is not essentially new, except in notation and method of presentation, and it appears unwarranted to label it as "The Bothezat Theory."

As a matter of fact, the argument advanced is essentially the blade element theory of Lanchester and Drzewiecki, which takes account of the incidence of an air stream upon the blade elements combined with the momentum theory of Riach and Page, which takes account of the relative velocity of the air stream in the neighborhood of the propeller. The combination of these two distinct propeller theories for the determination of the constants of a propeller was sugested in 1913 by Mr. Handley Page in England and was later developed into practical form for use in design by Riach, Page, Watts, and others in England who had been engaged in propeller design. An almost identical treatment was proposed by Betz in the *Zeitschrift für Flugtechnik*.

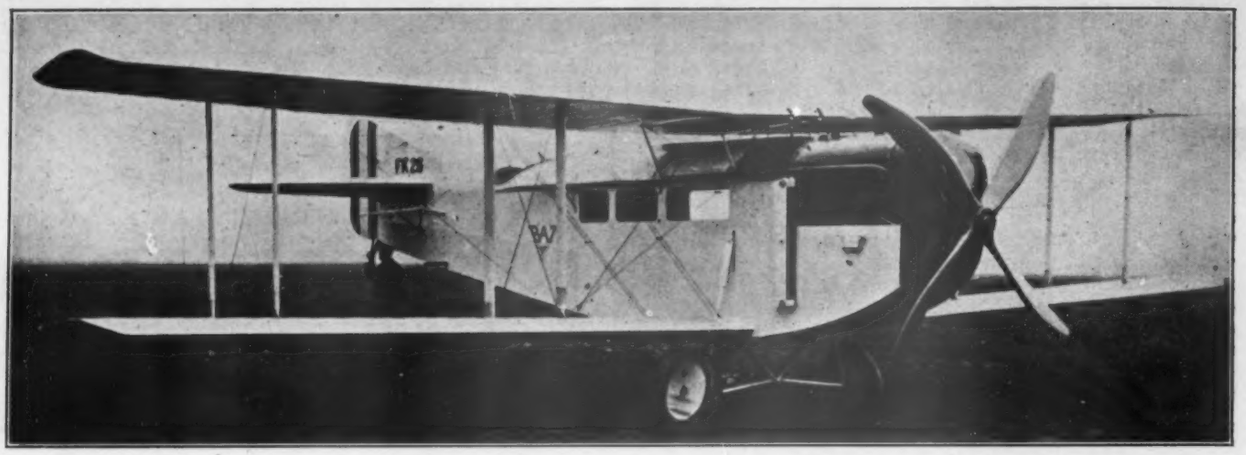
Dr. de Bothezat claims that, "the theory presents a complete picture of the whole phenomena of working of a blade screw." No propeller theory which rests upon physical assumptions which are not absolute can be complete. His statement that $v'' = 2v$ and $w'' = 2w$ for any blade element is not in agreement with the true phenomena, although it would be approximately so if applied to average values of v and w over the whole blade. With reference to the determination of K_x and K_y by a static test of a radial screw, it appears from the definition of the screw Ki = constant that the angle of attack is assumed constant along the blade. This is not in accordance with Eiffel's experiments. Furthermore, a radial screw as defined by a constant would, if constructed to give sufficient stiffness for test, have a very different shape from the average propeller and would have different hub and tip losses.

The discussion of propeller working, as presented by Dr. de Bothezat, is interesting and ingenious, but in spite of the skill of the manipulations of the symbols used the accuracy of the picture presented depends entirely upon fundamental assumptions which are not unreasonable, but certainly are less complex than our experiments indicate the actual phenomena to be.

Very truly yours,

J. C. HUNSAKER,
Comdr. (C. C.) U. S. N.

The B.A.T. Type F.K. 26 Transport Airplane



THREE-QUARTER FRONT VIEW OF THE B.A.T. TYPE F. K. 26 AIRPLANE
(C) Keystone Photo News

The B. A. T. type F. K. 26 transport airplane, produced by the British Aerial Transport Co., Ltd., to the designs of Mr. F. Koolhoven, chief engineer of the firm, is the first English airplane distinctly designed as a commercial machine. Not being a mere adaptation of a war airplane to civil needs, this machine is of considerable interest as an instance of English post-war design.

The F. K. 26 is a tractor biplane fitted with a specially designed cabin which affords accommodation for either four passengers or their equivalent weight in goods or mails.

The fuselage is very deep and embodies two forms of construction, the front half being made up of six formers covered with three-ply, the rear half following normal practice in wire-braced girder construction.

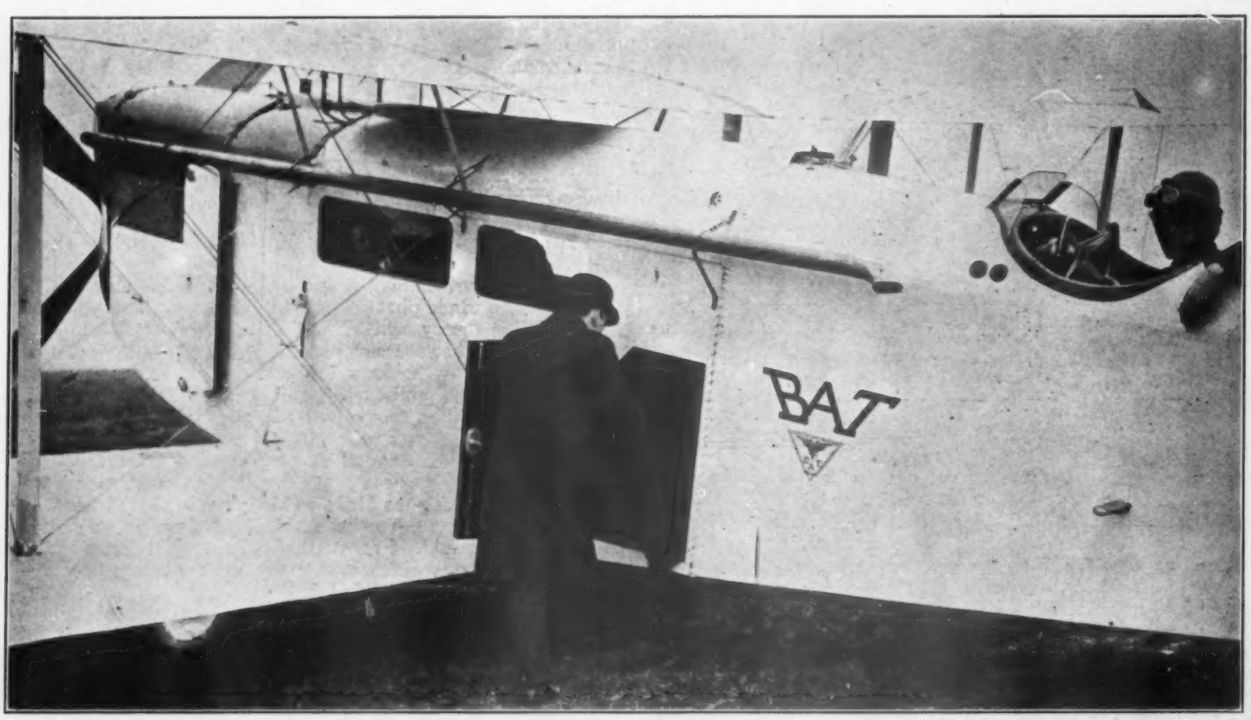
The power unit, a 375 hp. "Eagle" Mark VIII Rolls-Royce engine, is mounted on ash engine bearers carried between the first and second formers. Between the second and third formers, which are more or less bulkheads, are carried the gasoline tanks, which have a capacity sufficient for six hours' flying.

The space from the third to the fifth formers forms the cabin, the fourth former being left open, that is, it has no cross members or three-ply filling, as in the second, third, and fifth formers, the last two forming the front and rear "walls" of the cabin.

Aft of the cabin the wire-braced construction begins, and consists of a girder of six bays, the pilot's seat being situated between the second and third cross-members and well up in the fuselage, thus giving him an excellent view all round.

From the cabin aft the sides of the fuselage are fabric-covered, with a top fairing of three-ply.

The controls are similar to those of the old Deperdussin



CLOSE-UP VIEW OF THE PASSENGER CABIN AND PILOT COCKPIT
(C) Keystone Photo News

monoplanes, and consist of an inverted U-shaped member pivoted at the flooring of the cockpit, on which is mounted a wheel which has two segments cut from it top and bottom, as shown in the photograph of the pilot's cockpit.

The elevators are operated by two oval section tubes connected at their front ends to points one on either side halfway up the inverted U and at their rear end to crank-arms on the underside of the elevators, thus giving direct pull and push action.

The rudder control consists of the usual foot-bar.

The tail plane is adjustable, the actuating gear being operated by a wheel situated low down on the left-hand side of the pilot's seat, which is connected to a threaded spindle by a continuous cable. Above the tubular nut on the spindle is a collar connected to the front main spar of the tail plane by means of four tubes, two inside the fuselage either side of the central tube, and two streamline tubes running out the wings either side of the fuselage to a point on the front main spar of the tail plane.

The under-carriage consists of two Vees set across the fuselage, the apexes of which are connected fore and aft, and from the Vees two divided axles, two on either side, meet at a wheel hub. From the hubs two tubes run up to two levers which just project through the sides of the fuselage and which are pivoted at their innermost ends to the centre of the third fuselage former. The levers are connected near their outer ends to an oleo and elastic shock-absorber.

The main planes are of equal span, and are connected to upper and lower centre sections, the latter, consisting of two small false wings attached to the side of the fuselage which, with the width of the fuselage, are the same span as the upper centre section, thus the upper and lower main planes are of the same length and consequently interchangeable. The spars of the lower centre section pass right through the fuselage and are built into the third and fourth formers.

Two pairs of interplane struts are fitted on either side of the fuselage, braced with streamline wires.

The tail skid is pivoted to the base of the rudder and a pair of telescopic tubes containing a spring run from the toe of the skid to a lug some distance up the rudder post.

The engine-cooling system consists of two long honeycomb radiators which are carried on either side of the fuselage and connected to two water-tanks inside the fuselage, the temperature therein being controlled by two shutters operating at the back of the radiator.

The oil-tank has an extension which projects through the side of the fuselage and which has a series of tubes passing through it, thus forming an oil-cooler.

The following table gives the main particulars of this machine:

SPECIFICATION

Type of machine (pilot and 4 passengers)	Five-seater biplane
Name or type No. of machine	B.A.T. F.K.26
Purpose for which intended	Commercial passenger or mail carrying
Span	46 ft.
Chord	6 ft. 6 in.
Gap, maximum and minimum	6 ft. 6 in.
Stagger	Nil
Dihedral	2 deg. on both wings
Overall length	34 ft. 8 in.
Overall height	11 ft. 3 in.
Total area of wings	580 sq. ft.
Ailerons	Top and bottom
Area of each aileron and total area	4 × 13 sq. ft. = 52 sq. ft.
Span of tail	15 ft. 9 in.
Total area of tail	66.6 sq. ft. (including elevators)
Area of elevators	23.6 sq. ft.
Area of rudder	10.8 sq. ft.
Area of fin	8 sq. ft.
Maximum cross-section of body	20.5 sq. ft. approx.
Side area of body	142 sq. ft. approx.
Engine (type and max. b.hp.)	350 hp. Rolls-Royce "Eagle" 8
Propeller	B.A.T. 4-blade, 11 ft. dia. 8/6 in. pitch, 1025 r.p.m.
Weight of machine empty	2700 lb.
Load per sq. ft.	7.7 lb.
Weight per hp.	13.0 lb.
Tank capacity in hours at ¾ throttle	6 hr.
Tank capacity in gallons	100 gal.
Disposable load apart from fuel	1,000 lb.
Total weight of machine fully loaded	4,500 lb.
Performance—	
Speed low down	122 m.p.h.
Speed at 10,000 ft.	110 m.p.h.
Landing speed	50 m.p.h.
Climb—	
To 5,000 ft.	4 min.
To 10,000 ft.	10 min.
Ceiling	18,000

The Large Land Airplane in German Practice

By Erik Hildesheim, B.A.

In submitting photographs and somewhat inadequate information on large German airplanes of recent design, the writer has thought it interesting to survey briefly the development of the Giant Airplane.

One of the first builders of giant airplanes was the Russian engineer Sikorksy. His was a biplane, built at the Russo-Baltic Waggon Works in Riga, and equipped first with four 100 hp. German Argus motors, for which two 200 hp. Salmson engines were later substituted. The engines were in either case mounted on the lower planes on both sides of the tractor body. An enclosed cabin was provided for a dozen or more passengers, with an open platform in front, with searchlights for night landings. War time development of the Sikorsky airplanes was limited by lack of materials and motors. Nevertheless it is known that other Sikorsky machines of the four-engine type have been built during the war.

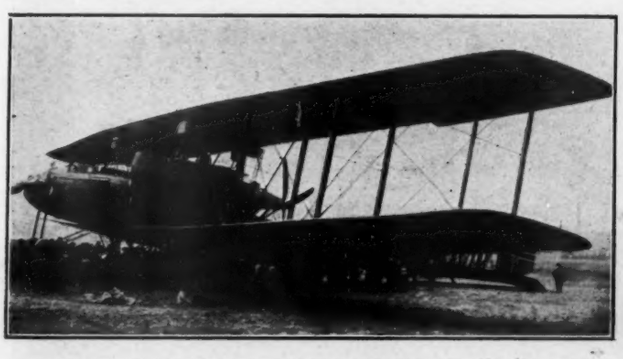


FIG. 1. FIVE-ENGINE STAAKEN-ZEPPELIN AIRPLANE

The first twin-engined airplane to be used to any large extent on active service was the French Caudron biplane, of the well-known tractor and tail boom type with two rotary or radial engines on either side of the central nacelle. The Caudron G. 6 was a three-seater of a similar type, and was used extensively for observation work. At the close of the war the Farman came to the fore with two Renault engines on the wings, and this type has been successfully adapted for commercial work since the signing of the armistice.

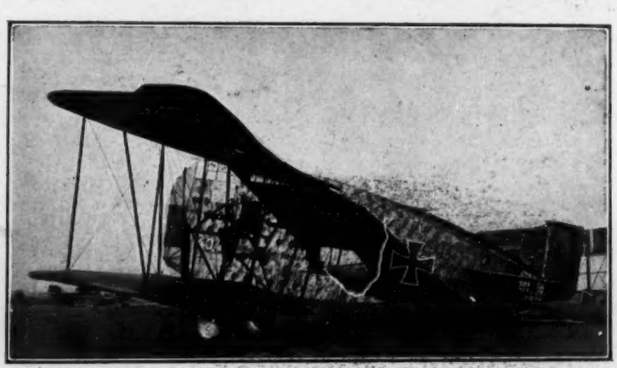


FIG. 2. FIRST LINKE-HOFFMANN AIRPLANE WITH TWIN TRACTOR SCREWS

Other large multi-engine machines were produced in France by Letord, Morane and Voisin.

In England we had the well-known twin-engine Handley-

FIG. 3. A LATER LINKE-HOFFMANN AIRPLANE, WITH FOUR ENGINES IN THE FUSELAGE AND A SINGLE TRACTOR AIRSCREW

Page and at the end of the war the most interesting four-engine Handley-Page, the engines being arranged in tandem on either side, with a front tractor and rear pusher propeller, the latter having a greater pitch. The Bristol biplane, of which we first heard of after the armistice was equipped with four Liberty engines, arranged in similar fashion to the giant Handley-Page.

The successful work of the three-engine Caproni is well known to all interested in Aeronautics.

In German practice a good deal of information has already been published regarding the A. E. G., Gotha and Friederichshafer bombers. Incidentally and the Germans may be said to have been the first to introduce these large planes for organized bombing raids.

Information is now at hand on several German machines, which have never been described in the English or American technical press.

Staaken-Zeppelin

The Zeppelin Co. developed a five engine plane from the Friederichshafen twin-engine bomber, termed the Staaken-Zeppelin, so named after the factory where it was built. This machine has been employed for both land and sea work, in the latter case being equipped with two long narrow floats. It carries five 260 hp. Maybach engines, four of which are fitted in tandem in two engine nacelles as in Fig. 1, while the fifth is mounted in the nose of the fuselage and drives a tractor screw. It is interesting to note that the other tandem engines only drive one propeller. A variation in this design provided four engines only, with the front of the central fuselage equipped as a passenger cabin. Seats for one mechanic are fitted in each engine nacelle, the mechanic serving at the same time as gunner; access is had to the gun position on the top plane through a rope ladder. Where four motors only were used, two observers were placed in the nose, while the

FIG. 4. FOUR-ENGINE LINKE-HOFFMANN AIRPLANE UNDER CONSTRUCTION

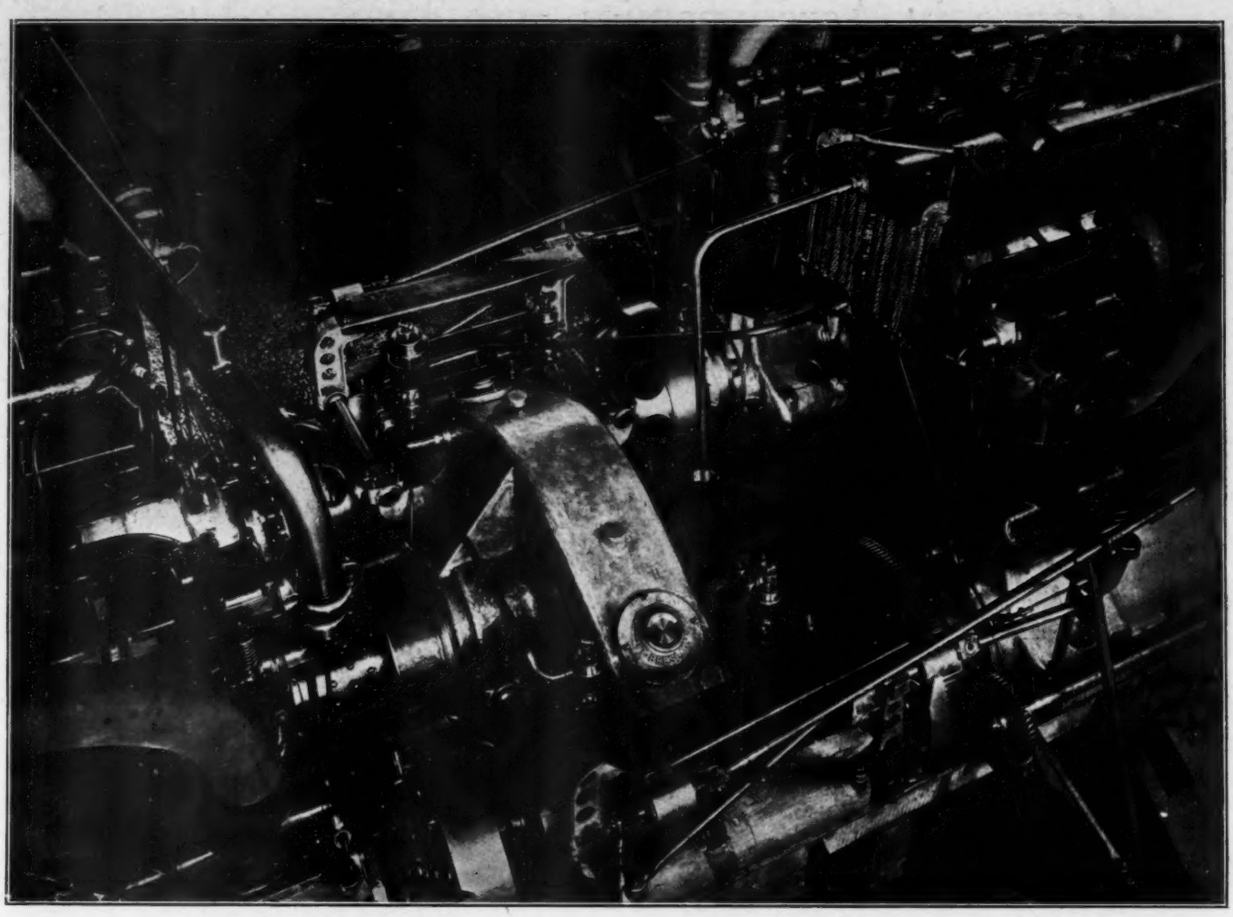


FIG. 5. ENGINES OF THE LINKE-HOFFMANN AIRPLANE UNDER TEST

two pilots were seated side by side in a cock-pit, with the commander and a companion at their back and a cock-pit for three observer-gunners aft.

The Linke-Hoffmann Airplanes

A formerly unknown concern, the Linke-Hoffman Co. of Breslau, has come very much to the fore in the production of a type with a very interesting central power group.

The first Linke-Hoffman is illustrated in Fig. 2. Apparently a freak design, it marked the way to later developments. It carried a twin tractor screw gear drive, and had a body of immense depth, presumably to provide enclosed comfort for the passengers. A curious feature was the embrasures provided in the sides of the fuselage to enable the gunners to fire sideways.

A later Linke-Hoffman airplane (Fig. 3) is all the more interesting because it is apparently an enlargement of the ordinary tractor biplane with all four engines in the fuselage and one tractor screw. It presents a most novel feature in the radiators which are carried on either side of the fuselage and are of aerofoil form.

A four engined Linke-Hoffman is shown in process of construction in Fig. 4. It carries in the rear a twin gun turret. The ribs are aparently of Handley-Page construction, while the spars are box-girders. The four vertical motors and the gear arrangement is shown under test in Fig. 5.

Air Mail Records

A record of 99 per cent was made by the Air Mail Service between Washington and New York for the month of June, covering a mileage of 11,118 and carrying 15,643 lb. of mail.

On the Cleveland-Chicago division a perfect score of 100 per cent was obtained. A total of 19,825 miles was run during the month of June on that division and a total of 19,603 lb. of mail was carried. The average speed on that route for the month was 97.8 m.p.h. The best flying was performed on June 18 when the round trip from Cleveland to Chicago and return was made in 6 hours and 14 minutes—an average of 104.4 m.p.h. in each direction.

The operation of the Cleveland-Chicago route is without a parallel in the history of aviation. The route was started May 15 and has never missed a day—70 consecutive, daily, non-stop flights of 325 miles each were made without a forced landing. On the 71st trip a gas line connection sprung a leak causing a forced landing on the emergency air mail landing field at Bryan, Ohio.

On July 4 there were on the mail route between Washington and New York, New York and Cleveland and Cleveland and Chicago, ten planes in flight. The shortest route was 215 miles from New York to Bellefonte, Pa., and the longest route was from Cleveland to Chicago or 325 miles.

Return of the R-34

The British naval airship R-34, which flew from East Fortune air station, Scotland, to Roosevelt Field, Long Island, N. Y. in 4 days 12 hr. 12 min., successfully completed her round trip across the Atlantic on July 13, when she reached Pulham air station, Norfolk, England, after a flight of 3 days, 3 hr. 3 min. The eastward passage was made at an average altitude of 3000 ft. and with favoring winds practically all the way across which at times increased the speed of the airship to 74 m.p.h.

Col. W. N. Hensley, U. S. A., representing the War Department, was a passenger on board the R-34 at the invitation of the British Air Ministry.

Course in Aerodynamics and Airplane Design

Part III.—Experimental Aeronautical Engineering

By Alexander Klemin

Technical Editor, Aviation and Aeronautical Engineering; Consulting Engineer, Aerial Mail Service; Consulting Aeronautical Engineer

Section 6 Instruments for Full Flight Testing—*Continued*

Calibration of Air Speed Meter

An air speed indicator may be calibrated by the use of a whirling arm, or in a wind tunnel, but, however well it may be calibrated or however carefully placed on the plane to avoid interference, it should be calibrated in actual flight before each important test.

A calibration test should, if possible, be conducted at an altitude of 50 to 100 ft. in order to insure accuracy in making ground observations. The course should be at least two miles long, and if possible three, and should be situated in such a field or country that the pilot may make a landing anywhere on the course in case of necessity. At each end

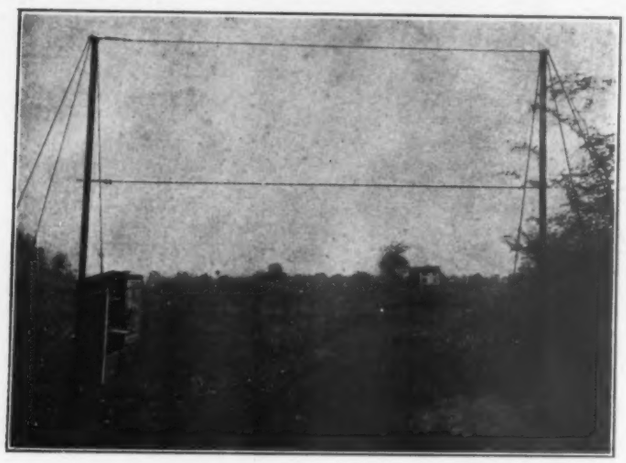


FIG. 1

of the course there should be sufficient clear country so that the pilot may attain a constant speed before passing the starting point in either direction.

When the course has been established, easily visible landmarks and sighting wires are set up at each end. At each end of the measured course two upright standards are erected at right angles to the course, located about twenty feet apart and are plumbed vertical. This arrangement is clearly shown in Fig. 1, the upper wire being about 15 ft. above the ground and the lower 6 ft. below the upper one. A trained observer must be stationed at each end of the course.

By use of the telephone, communication is established between the ends of the course and results can be readily compared.

As the airplane approaches the starting end the observer at that end warns the one at the other end, and as the plane crosses over the starting wires, he calls time and starts his stop watch, the other observer starting his watch at the same time. When the plane crosses the finishing line, the same signal is given by the second observer and both men stop their watches. It can be seen that by this method the man at the finish starts his watch late while the man at the start stops his watch late. The means of the two records can be taken as reasonably accurate. In some cases electric light signals are used, the observer at the start lighting the lights the moment the machine passes, and so signalling the observer at the other end. In the same manner, the observer at the finish signals the starter by opening a switch and so putting out the lights.

These tests should be conducted early in the morning or evening, when the weather is most likely to be calm. The velocity of the wind should not exceed 5 m.p.h.

The calibration should be made at the maximum speed, the minimum speed, and several intermediate speeds. At each speed there should be two trips each way, or four trips in all.

Whenever possible, instruments of the recording type should be used. The instruments required in the pilot's cockpit are as follows:

1. A statoscope to assist him in maintaining a constant level.
2. An altimeter.
3. A direct reading tachometer, so that he can keep his engine running at a constant speed and thus maintain a steady flying speed.
4. An air speed meter to assist in maintaining a constant speed.
5. Inlet and outlet radiator thermometers to enable the pilot to check the performance of the engine.

The instruments required in the observer's cockpit are as follows:

1. A calibrated air speed meter from which the observer takes periodic readings.
2. A strut thermometer, either recording or direct reading.
3. A recording barograph, or direct reading altimeter to be used as a pressure measuring device.

As an actual example of the computations involved in a test, the complete record of calibration for a Sperry type instrument on a Lewis & Vought advanced training machine is reproduced herewith. In tables I and II are given the ground observer's and the flying observer's data sheets. The

TABLE I. CALIBRATION OF AIR SPEED METER

Ground Observer's Data Sheet — Date: May 17, 1918

Airplane: Lewis & Vought — Station: North End of Course — No. P-23
Air Speed Meter: Sperry — Type: Adv. Training — Type: M.C. — No. 7

Trial	Direction of Flight	Mean time over 2-mile course	Time when Observations Taken	Wind Velocity m.p.h.	Direction of wind
1	N.	1:05.5	8:35 A.M.	4.5	N 50° E
2	S.	1:07.4	8:38 A.M.	4.5	N 60° E
3	N.	1:05.6	8:42 A.M.	4.5	N 60° E
4	S.	1:07.9	8:45 A.M.	4.5	N 50° E
5	N.	1:14.25	8:49 A.M.	4.0	N 50° E
6	S.	1:15.9	8:53 A.M.	4.0	N 50° E
7	N.	1:13.25	8:57 A.M.	4.5	N 50° E
8	S.	1:16.15	9:01 A.M.	4.0	N 50° E
9	N.	1:26.5	9:05 A.M.	4.5	N 60° E
10	S.	1:27.15	9:09 A.M.	4.5	N 60° E
11	N.	1:25.5	9:15 A.M.	4.5	N 60° E
12	S.	1:30.2	9:20 A.M.	4.5	N 60° E

TABLE II. CALIBRATION OF AIR SPEED METER

Flying Observer's Data Sheet — Date: May 17, 1918

Airplane: Lewis & Vought — Type: Adv. Training — No. P-23
Air Speed Meter: Sperry — Type: M.C. — No. 7

Trial	Direction of Flight	Air Speed Readings	Average Air Speed	Altitude	Strut Temperature	R.P.M. of Engine
1	N.	105 106 106.0 106.5 106.5	106	1000	27° C	1713
2	S.	106 105.5 106.0 106.5 106	106	1000	28° C	1706
3	N.	106.5 107 107 107.5 107	107	1000	26° C	1720
4	S.	106 106 106 106.5 105.5	106	1000	26° C	1710
5	N.	95 95 95 95 95 95.5	95	1000	27° C	1520
6	S.	94.5 95 95 95 95 95.5	95	1000	26° C	1520
7	N.	96 95.5 95 95 94.5 94	95	1000	26° C	1520
8	S.	95 95 94.5 95 95 95.5	95	1000	26° C	1520
9	N.	81 82 81 81.5 83 82.5	82	1000	25° C	1380
10	S.	85 82 82 81 81 81	82	1000	25° C	1370
11	N.	82 83 84 83 83.5 82.5	83	1000	25° C	1376
12	S.	79 80 80 80.5 79.5 80	80	1000	25° C	1370

TABLE III. REDUCTION OF DATA FOR CALIBRATION OF AIR SPEED METER

Airplane: Lewis & Vought Type: Adv. Training Tractor Biplane No. P-23
Air Speed Meter: Sperry Type: M.C. No. 7
Ground Temperature: 76 deg. Fahr. Barometer: 29.5 in. mercury. McCook Field. May 17, 1918.

Trial	Direction of Flight	Time of Flight	Computed Speed	Wind Velocity	Angle with course	Wind correction	Air Speed corrected for wind	Observed air speed	Altimeter reading	Corresponding pressure for standard altimeter calibrated at 50 deg. Fahr. or 10 deg. Cent.	Strut temperature calibration 3½ deg. Cent.	Density as ratio of standard at 16 deg. Cent. and 29.92 in. mercury	Corrected air speed	Correction	R.p.m. calibration (add 10 r.p.m.)
1	N.	1:05.5	110.0	4.5	66°	−1.8	108.2	106	1000	28.3	22½° C	.942	109.3	−1.1	1723
2	S.	1:07.4	107.0	4.5	76°	+1.0	108.0	106	1000	28.3	21½° C	.946	109.0	−1.0	1716
3	N.	1:05.6	109.7	4.5	76°	−1.0	108.7	107	1000	28.3	21½° C	.946	110.0	−1.3	1730
4	S.	1:07.9	106.0	4.5	66°	+1.8	107.8	106	1000	28.3	21½° C	.946	109.0	−1.2	1720
5	N.	1:14.25	97.0	4.0	66°	−1.6	95.4	95	1000	28.3	22½° C	.942	98.0	−2.6	1530
6	S.	1:15.9	95.0	4.0	66°	+1.6	96.6	95	1000	28.3	21½° C	.946	97.8	−1.2	1530
7	N.	1:13.25	98.4	4.0	66°	−1.6	96.8	95	1000	28.3	21½° C	.946	97.8	−1.0	1530
8	S.	1:16.15	94.5	4.0	66°	+1.6	96.1	95	1000	28.3	21½° C	.946	97.8	−1.7	1530
9	N.	1:26.5	83.3	4.5	76°	−1.1	82.2	82	1000	28.3	20½° C	.949	83.7	−1.5	1390
10	S.	1:27.15	82.6	4.5	76°	+1.1	83.7	82	1000	28.3	20½° C	.949	83.7	0	1300
11	N.	1:25.5	84.2	4.5	76°	−1.1	83.1	83	1000	28.3	20½° C	.949	84.8	−1.7	1386
12	S.	1:30.2	79.9	4.5	76°	+1.1	81.0	80	1000	28.3	20½° C	.949	81.7	−0.7	1380

readings of the ground anemometer and the observations in the air were taken simultaneously, so as to secure complete synchronization. The main criticism of this calibration is that it was taken at an altitude of 1000 ft. instead of at 50 ft. as recommended. It was impossible to make the tests at the lower altitude on account of the rough character of the country.

Reduction of Data—In the columns of table III the data contained in tables I and II are reduced step by step until the calibration correction is obtained. Columns 1, 2, 3, and 5 (in table III) are copied directly from the observations. Thus for Trial 1, the length of the course being 2 miles and the time over the course being 65.5 sec. the computed speed is

$$\frac{3600}{65.5} \times 2 = 110.0 \text{ m.p.h.}$$

Column 6—The course having a bearing of almost 16 deg. west of north, and the wind blowing 50 deg. east of north, the direction of the wind relative to the course is 50 + 16 = 66 deg. The wind correction or component of the wind aiding or retarding the flight (column 7) is 4.5 cos 66 deg. = 1.8. As the wind aids the machine in its flights northward and retards it in its southbound flights, the wind correction must be deducted from the computed speed for the northbound flights and added for the southbound. This gives the corrected air speeds as shown in column 8.

Columns 9 and 10 are taken directly from the flying observer's sheet, while column 11 is taken from the altimeter calibration curve. Since this instrument was not set at zero but in agreement with barometric pressure at ground level, it may be used as a purely pressure instrument. The corresponding pressure taken from the calibration curve is 28.3 in. of mercury.

Column 12 is taken from the flying observer's sheet. Column 13 is obtained from chart in previous section of the course where for any pressure and temperature the ratio to air at standard density (16 deg. C. and 29.92 in. mercury) is given.

Column 14 is obtained by multiplying the observed air speed by the inverse square root of the density ratio, as explained in previous sections. The final calibration corrections are given in column 15. No calibration curves need be drawn in this case as the correction is almost exactly —1.25 m.p.h.

New Type of Rigid Airship Construction

A new design for rigid airships which seems to eliminate most of the drawbacks of the existing types forms the subject of a recent British patent which has been taken out by a well-known firm of English motor boat and yacht builders.

In this design the hull of the airship is formed by a gas-tight shell made of several thin layers of wood veneer with layers of fabric between them, the whole being cemented and stitched together with fine copper wire, and internally stiffened by longitudinal and transverse girders.

Such a monocoque hull offers several advantages over the conventional fabric-covered girder type. First, owing to the fact that the shell acts at the same time as framework, outer cover and gas container, the monocoque design is for the same size stronger—or for the same weight lighter—than the Zeppelin type. Second, the veneer shell eliminates the tedious adjustment of the wire stays which brace the girder type athwartship and longitudinally, the transverse bracing being insured by veneer bulkheads which subdivide the gas container into compartments.

Third, head resistance is reduced to a minimum, because no external projections beside fins and rudders occur on the hull, the machinery and accommodations being situated inside. The latter are separated from the gas container by a double wall, the space between which is filled with an inert gas, such as nitrogen, to reduce the fire risk when hydrogen is employed as a lifting gas. With the use of helium—which is non-inflammable—this double wall could most likely be done with entirely. The reduction of head resistance effected by such a design, where the airship is a strictly streamlined body, must obviously result in a considerable increase of speed for the same power.

Fourth, the monocoque hull promises to solve the much tangled problem of conserving the lifting gas for continued use, that is, without losing it through leakage or having it deteriorate by air penetrating the gas container owing to the imperfect gas tightness of existing balloon fabrics and their gradual deterioration due to sunlight. It is believed that a veneer hull, suitably lined with gas impervious fabric will insure an almost perfect gas tightness. Fifth, the airship will be entirely weatherproof; this will make it possible to moor it as a rule in the open, either to ground anchorages or to mooring towers, and use the costly hangars only for overhauling and assembling. The greater strength of the monocoque hull as well as the better facilities it offers for the attachment of mooring and handling ropes will also simplify the problem of mooring airships in the open.

Finally, the weather proof quality of the hull will make such an airship virtually unsinkable—a feature which has considerable merit for oceanic air transport, where safety considerations must be of primordial importance.—L. D'O.

Resistance of Nose Radiators*

The present report considers the effect of placing a radiator in the nose of a fuselage as compared with the effect of placing a radiator of the same core construction, having an equivalent cooling capacity, in the free air, and streamlining the nose of the fuselage. The results of these tests indicate less difference than would be shown by comparing results with radiators specially selected for each of the positions in which they were placed.

The results are qualitative only, but they are so striking as to indicate that the nose of the fuselage is not a desirable location for a radiator from the point of view of head resistance.

A model fuselage 60 in. long, 10 in. wide and 13 in. high was constructed with a removable streamline nose, which, when removed, allowed an 8 in. square section of radiator core to

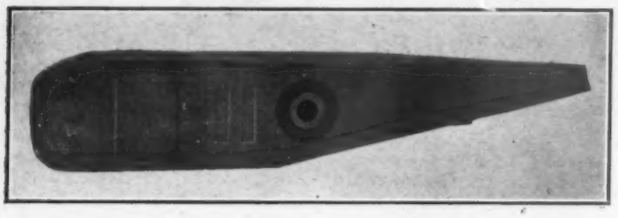


FIG. 1

be placed in the nose (see Figs. 1 and 2). Two holes on each side of the fuselage, each about 1½ in. by 6½ in., were cut about a foot back from the nose and fitted with adjustable sliding doors. By adjusting these vents the amount of air passing through the nose was varied.

The model was mounted in a 54 in. wind tunnel and the head resistance measured under the following conditions:

(1) Streamline nose on model. (No change in resistance was observed whether vents were open or closed.)

(2) Streamline nose removed, but nose radiator covered with a sheet of paper so that there was no air flow through the core. (3), (4) and (5) Nose radiator in place with varying amounts of air flow controlled by opening the vents. Seven or eight different air speeds were tried in each case, the maximum being about 70 m.p.h.

The results of these runs are given in Fig. 3, against free air speed. They show (1) that the streamline nose decreases the resistance of the fuselage by 50 per cent, and (2) that the total resistance of the fuselage increases rapidly when air is allowed to enter the radiator, so that a compact type of core is desirable for this position.

Fig. 4 illustrates these conclusions more clearly, since there the resistance of the fuselage at 60 m.p.h. free air speed is

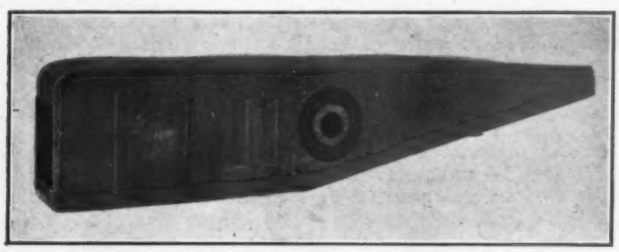


FIG. 2

plotted against the mass flow of air through the radiator. There is also plotted the total resistance of the fuselage with a streamline nose together with a free air radiator of the same core construction and of such size as to have a cooling capacity equivalent to that of the nose radiator at any given mass flow. Figs. 5 and 6 give the same data for a core of very high head resistance, which would be a very good type for a nose radiator and a very bad type for free air. There

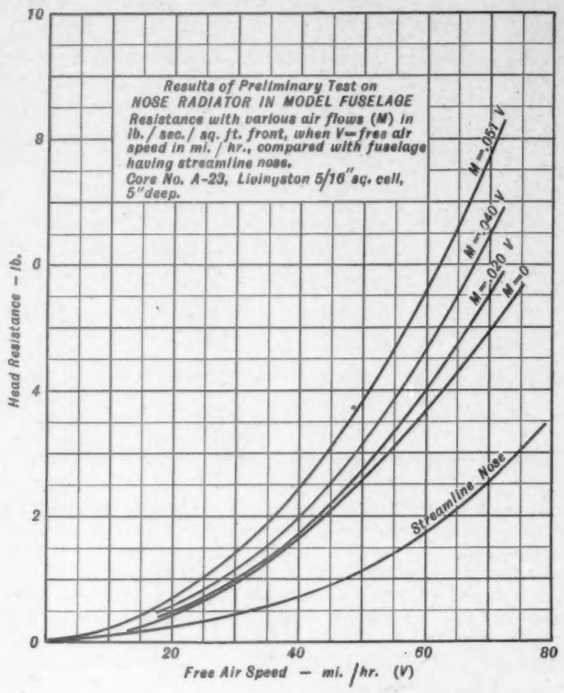


FIG. 3

are types of core considerably better for free air positions than those included in this test, but the core represented in Figs. 5 and 6 is probably one of the best for the nose position.

These wind tunnel tests show the following qualitative results:

(1) At any given plane speed the total resistance of a fuselage with a flat nose radiator is increased by increasing the air flow through the radiator, either by opening exit vents for the air or by decreasing the resistance of the radiator to passage of air. This shows that a nose radiator—in contradistinction to a free air radiator—should be of compact construc-

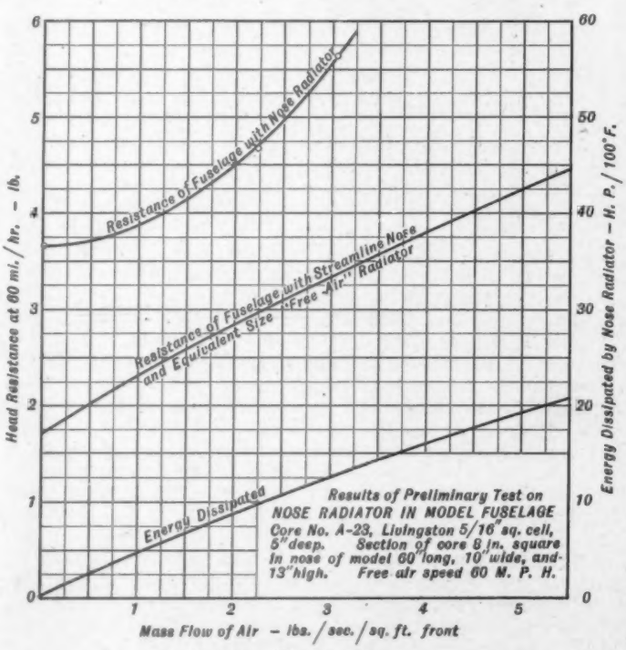

Resistance of Fuselage with Nose Radiator
Resistance of Fuselage with Streamline Nose and Equivalent Size "Free Air" Radiator
Energy Dissipated
Results of Preliminary Test on
NOSE RADIATOR IN MODEL FUSELAGE
Core No. A-23, Livingston 5/16" sq. cell, 5" deep. Section of core 8 in. square in nose of model 60" long, 10" wide, and 13" high. Free air speed 60 M. P. H.
Head Resistance at 60 mi./hr. - lb.
Energy Dissipated by Nose Radiator - H. P./100°F.
Mass Flow of Air - lbs./sec./sq. ft. front
0
1
2
3
4
5
6
10
20
30
40
50
60

FIG. 4

* Aeronautic Power Plants Report No. 24, National Advisory Committee for Aeronautics.

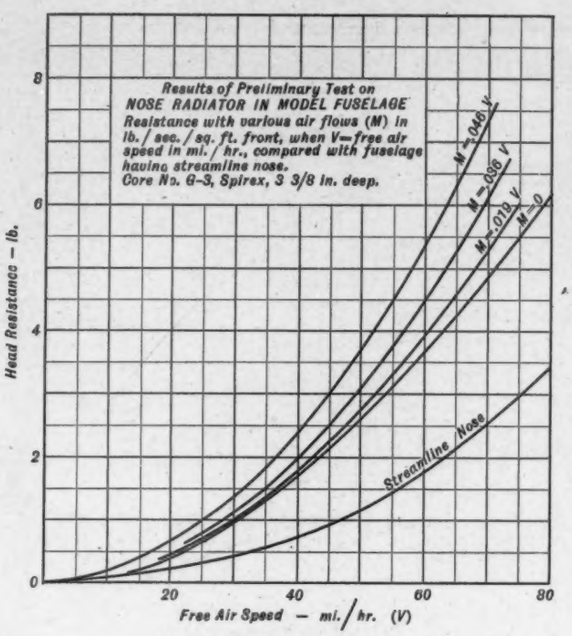


FIG. 5

tion with high heat transfer for low air flows through the core, therefore requiring a core of high resistance.

(2) With varying plane speeds the relative efficiencies of free air and nose radiators do not change.

(3) With all three widely different types of core tried, the combined resistance of the fuselage and a free air radiator of given cooling capacity, was from 10 to 50 per cent less than that of the fuselage with a nose radiator of the same core construction and equivalent cooling capacity.

(4) From other experiments performed at the Bureau of Standards it is clear that there is more chance for improvement in types of core for free air positions than in types of cores for the nose position.

Based on the results of these wind tunnel experiments it is concluded that:

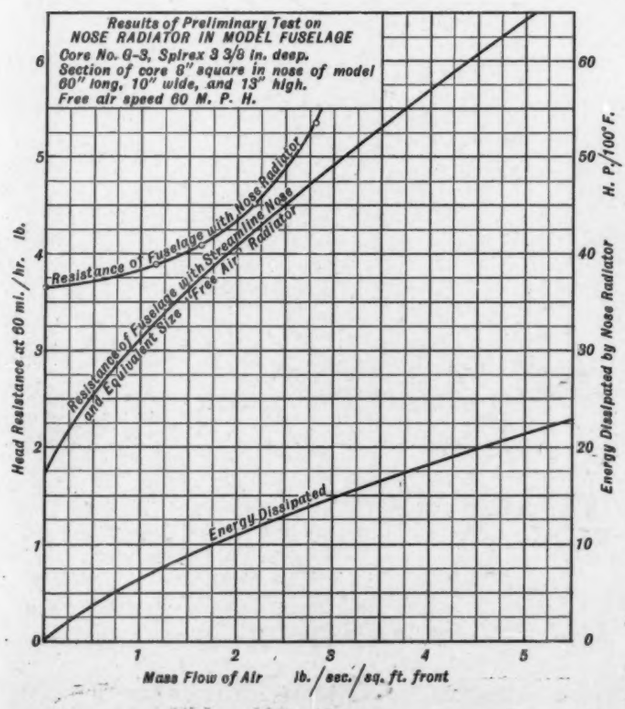


FIG. 6

(1) The resistance of a fuselage with streamline nose is increased more by removing the streamline nose and substituting a radiator than it is by adding an equivalent free air radiator and retaining the streamline nose.

(2) Between good radiators for each position the increase of resistance due to the nose radiator is roughly double that due to the free air radiator.

(3) Above a very low mass flow, the nose radiator becomes relatively worse and worse as the mass flow is increased by opening the vents at a constant free air speed. This fact is of great importance, since the space available for a nose radiator is so limited that the highest possible mass flows are used in practice.

(4) It is found that the relative efficiency of the nose radiator and the free air radiator does not change appreciably with free air speed for a given setting of the vents.

Big Hangars for Navy

The Navy Department is soon to start the construction of two of the largest airship hangars in the world, authority for which is granted in the new naval appropriation bill.

Rear-Admirals Taylor and Parks, heads of the bureaus of construction and repairs and yards and docks, respectively, have instructions to speed up preparation of the working plans, as an expenditure of about $3,500,000 for two hangars to house machines of the Zeppelin type has been authorized. They will be located on the seaboard, probably in New Jersey, and possibly on the same site.

Ground area necessary for construction of a double hangar will be about one square mile. Each hangar will be about 800 ft. long, 250 ft. wide and from 150 to 200 ft. high. It is probable that all steel construction will be used, and officials estimate that from six to eight months will be needed for their erection.

Provision for the purchase abroad of an airship at a cost not to exceed $2,500,000 is made in the naval bill, and the construction in this country of a similar machine, at a cost of $1,500,000.

It is probable that the machine purchased abroad will be of the British R-34 model, although larger. It probably will be flown to this country by an American crew. Negotiations looking to the purchase have been entered into with foreign nations.

World Flying Rules

Principles to govern aerial navigation, already accepted by most of the allied nations, have been made public by the Aeronautical Commission of the Peace Conference, which recently concluded its work. These principles are contained in an international convention which provides for the creation of an international commission.

The principles laid down concern the nationality of, certificates of navigability, rules for flying, lists of forbidden routes, steps to be taken by all signatory nations to develop aerial navigation, various provisions governing the licensing of aviators, equipment of with signals, distribution of weather reports, and customs regulations.

R-33 Will Fly to India

It is stated that, following shortly the return of the R-34 from America, her sister airship, the R-33, will proceed on a voyage to India. As in the case of the Atlantic flight, the journey already has been made by air, though the first trip, that by a twin-engined Handley-Page airplane, was divided into two stages, with a big interval, while the bomber was engaged in final operations in Palestine.

At the end of last year a big four-engined Handley-Page machine set out to make the journey to India, and owing to various delays on the way did not actually reach her destination until January of this year.

Curtiss

There's Money in the Air

They say "Opportunity knocks once at every man's door."

'Tis knocking now at the door of every aviator while hundreds of young men are training for the commercial end of aeronautics.

And flying *is* now a business, although, first of all, it was a sport so full of sensation, adventure and thrill as to appeal to red-blooded men the world over.

But now the "bird of wood and iron" has got down to business and is "doing its bit" in the workaday world.

Here, for example, are some aircraft-activities of which many people do not know: (See also sketches on opposite page.)

Commuting
Taxi-Service
Aerial Express
Flights for guests at hotels and summer resorts
Campaigning
Selecting Land Sites
Oilfield Survey
Carrying Pay-rolls
Delivering Fresh Fish
Civic Planning
Food Distribution
Flying Contests
Film Delivery
Aviation Schools
Transportation of Government Officials
Laying out Logging Routes
Mail Carrying
Forest Fire Patrol
Aerial Photography
Making Motion Picture Films
Ranching
Missionary Work
Commercial Traveling
Delivering Clearing Papers
Fire Surveys
Carrying Prisoners
Visiting Remote Points
Railroad Survey
Passport Delivery
Aerial Prize-contests
Chamber of Commerce Reports
Carrying Samples of Minerals and Timber
Aerial Advertising
Astronomical Observation
Emergency Medical Service
Marketing Garden Truck
Sheep and Cattle Herding
Scouting for Market-fish
Soliciting Towing Business
Surveys of Docking
Delivery of Perishables
Flying Circuses
Aerial Preaching
Machine-part Delivery
Polar Exploration
Baseball Transportation
Ambulance Work
Wheatfield Survey
Air Exploration
Boundary Patrol
Real Estate Survey
Carrying Precious Ore
Quick Delivery of Merchandise
Fur-carrying
Hospital Transfer Work
Delivering Newspapers
Railway Terminal Surveys
Southern Plantation Travel
Flying Acrobatics
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Life Guard
Carrying Reporters
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Delivering Mail at Sea
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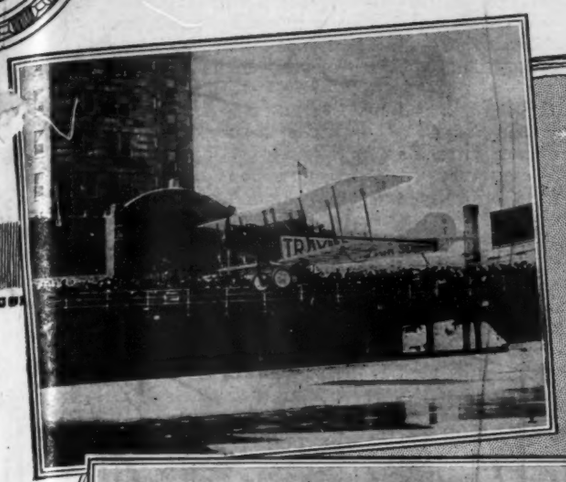
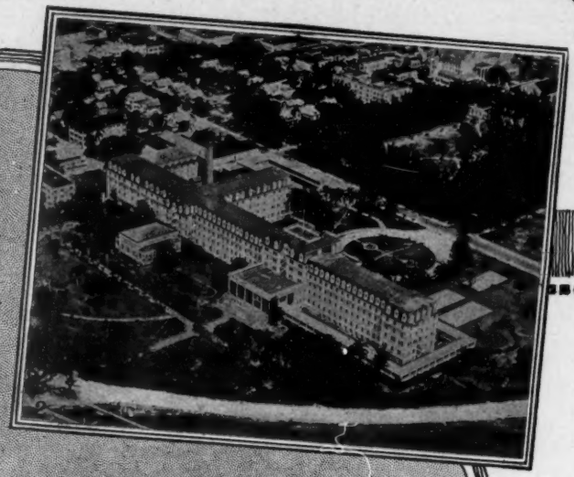




1—HOTEL AERIAL SERVICE
2—AERIAL PHOTOGRAPHY
3—CURTISS MAIL PLANE
4—DOCTOR'S AERIAL SERVICE
5—MERCANTILE SPECIAL DELIVERY
6—MUNICIPAL PATROL

Six of the hundreds of similar photographs showing widespread use of aeroplanes.

Production of Helium for Use in Airships*

One of the great scientific and technical triumphs resulting from the application of exact knowledge and inventive genius to problems of military importance has been the large-scale production of helium, making this hitherto exceedingly rare gas available for use in balloons and airships. The following account of the bureau's work in connection with helium was prepared by Dr. Andrew Stewart.

Discovery of Helium

During the solar eclipse of Aug. 18, 1868, P. J. C. Janssen noted in the solar chromosphere a bright yellow line near to but not identical with the D_1 and D_2 lines of sodium. Frankland and Lockyer called the line D_3 and, as it was referable to no known terrestrial substance, ascribed it to a hypothetical element which they called *helium,* from the Greek word *helios,* the sun.

In 1889, Dr. W. F. Hillebrand, of the United States Geological Survey, reported in the American Journal of Science that in analytical work on uraninite, which he began in 1888, he had obtained up to 2½ per cent by weight of a peculiar gas by treating the mineral with non-oxidizing inorganic acids. This gas had the characteristics of nitrogen, yet was different from any nitrogen known, and was thought by Hillebrand, on purely negative grounds, to be some allotropic form of that element. Lack of proper equipment, however, precluded any further researches on the subject. As a matter of fact, a certain percentage of the gas so found by Hillebrand was nitrogen.

The attention of Sir William Ramsay, the distinguished British chemist, was later drawn to Hillebrand's work, and he repeated the latter's experiments. He separated from cleveite, a variety of uraninite, a gas identical with that of Hillebrand, in the spectrum of which was found, with Sir William Crookes' aid, the D_3 line of Janssen, proving that in the gas there was present a new element, to which the name "helium," borrowed from Frankland and Lockyer, was given. On sparking this gas with oxygen to eliminate nitrogen, removing the excess oxygen with phosphorus, introducing the residual gas into an exhausted spectrum tube and passing an electric current through it, a bright yellow glow was obtained. Examined with a spectroscope, this glow gave rise to a series of lines in the red, green, and blue, but most prominent was the bright yellow line of Janssen. In 1895 the characteristic line of this gas was discovered in the spectrum of the atmosphere by Kayser, and the element was isolated from the air by Ramsay and Travers in the same year.

Occurrence and Properties

Helium is widely distributed in nature, but generally in minute quantities. The amount of it in the earth's atmosphere is exceedingly small, being present in the proportion of only 1 volume to 250,000 volumes of air. It has been found, as mentioned above, imprisoned within radioactive mineral substances, in the gases evolved from some thermal springs, in those emanating from volcanoes, and also in the natural gas of several gas fields in the United States (notably in Kansas, Oklahoma, Ohio, and also Texas). In some of the natural gas of this country helium is present in amounts as high as 2½ per cent. Of late, emissions of helium in comparatively large quantity have been reported from the boric acid soffione of Larderello, Tuscany, Italy. It issues from the earth at Stassfurt, Germany, and at Karlsbad. The natural gas in certain parts of Europe also contains helium, but in much smaller quantity than in our own.

Helium is one of a series of very rare, inert gases—other members being neon, argon, krypton and xenon—all of which are present in very small quantities in the atmosphere. Thus far every attempt to make these gases enter into chemical combination has failed. Helium is, next to hydrogen, the lightest of known substances. The gas, although twice as heavy as hydrogen, has in balloons a buoyancy or ascensional power of 92.6 per cent, as compared with the latter. The reason for this is that the buoyancy of a gas is measured not directly by its weight, but by the difference between its weight and that of the air displaced. Both hydrogen and helium are so light as compared with air that the difference in their lifting power is relatively insignificant. For example, 1,000 cu. ft. of pure hydrogen will lift a weight of 75.14 lb. whereas the same amount of pure helium will lift 69.58 lb., and a mixture, containing 85 per cent helium and 15 per cent hydrogen, which is the gas contemplated for all-around aircraft use, will have 93.4 per cent of the lifting power of hydrogen and will lift 70.18 lb.

In its physical behavior, helium is the nearest approximation to the ideal perfect gas. It is monatomic and liquefies at even lower temperatures than hydrogen. By its evaporation in vacuum, Onnes, of Leyden, produced it in liquid form, first cooling it in solid hydrogen and then expanding it through a small nozzle. Liquefied helium is a colorless, mobile liquid, having a density of 0.122; hence it is the lightest liquid known. It boils at 4.5 deg. absolute, and has a critical temperature of about 5 deg. absolute, with a critical pressure of 2.75 atmospheres. By the rapid evaporation of liquid helium, a temperature below 2.5 deg. absolute has been reached, but solid helium has not been produced. The low dielectric strength of helium permits electric discharges to pass through it with much greater ease than through most gases, and its conductivity for heat is very high.

Helium has been proved to be the end product of the emanations of radioactive substances, but the origin of its presence in natural gas has not been established. The helium content of some natural gas is relatively so large and the radiation from radioactive material is so small that derivation from such material would seem entirely out of the question. In the whole world not more than three ounces of radium have yet been isolated; but it must be remembered that radioactive material is very widely distributed in nature and that helium generation has been going on through countless ages of past time. A great many factors enter into consideration in this question, however, and it is difficult to set up an unassailable hypothesis regarding it.

Initiation of the Research Work

Up to Apr., 1918, helium had been obtained only in extremely small amounts, as a curiosity in scientific laboratories, so that the total quantity separated in the whole world probably did not exceed 100 cu. ft., the cost of production being about $1,700 to $2,000 per cu. ft. Hence, although the possibility of helium as a lifting gas had been realized, its practical use seemed out of the question.

In the development of a process by which helium is now being produced in large quantities, the Bureau of Mines was the pioneer and has taken the leading part. In Mar., 1916, the Director of the Bureau of Mines called the attention of Dr. F. G. Cottrell, chief metallurgist of the bureau, to a new process for air separation that embodied some novel and striking features, the bureau being interested then in the cheap production of oxygen for use in blast furnaces. This process had been evolved by Fred E. Norton, a graduate of the Massachusetts Institute of Technology and an engineer of wide experience and international reputation; Mr. Norton had pooled his patents with E. A. W. Jefferies and the consolidation became known as the Jefferies-Norton processes.

On Feb. 28, 1915, Sir William Ramsay wrote to Dr. R. B. Moore, of the Bureau of Mines, who had worked with him in investigating the rare gases of the atmosphere. Sir William said, among other things: "I have investigated blowers—that is, coal-damp rush of gas—for helium for our Government. There does not appear to be anything in the English blowers, but I am getting samples from Canada and the States. The idea is to use helium for airships."

As the United States was not yet in the war and strict neutrality was being maintained by this country, these remarks were passed over by Dr. Moore, but he remembered that in 1907 Dr. H. P. Cady, of the University of Kansas, had found more than 1 per cent of helium in some natural gas from Kansas, and he realized what it would mean if such helium could be made available for balloons and airships. Dr. Cady and D. F. McFarland were the first investigators to discover helium in natural gas; in 1907 they published a paper on the subject in the Journal of the American Chemical Society.†

* From the Bulletin of the Bureau of Mines.

† Cady, H. P., and McFarland, D. F., the occurrence of helium in natural gas and the composition of natural gas: Jour. Am. Chem. Soc., vol. 29, 1907, pp. 1523 et seq.

In Apr., 1917, Dr. Moore attended a meeting of the American Chemical Society in Kansas City, Mo., where a paper on rare gases was read by Dr. C. W. Seibel, of the University of Kansas, who had worked under Dr. Cady. In the discussion that followed Dr. Moore pointed out the possibility of helium for war-balloon use if its separation from natural gas could be accomplished at a reasonable cost. He asked Dr. C. L. Parsons, chief chemist of the Bureau of Mines, who was present at the meeting, to take up the matter with bureau officials on his return to Washington, and this Dr. Parsons did.

In Apr., 1917, the Director of the Bureau of Mines placed G. A. Burrell (later Col. Burrell) in charge of the bureau's war-gas work. The Bureau of Mines had initiated this work, chiefly on gas masks, smoke screens, and toxic gases, in cooperation with the Army and the Navy. Mr. Burrell, who had been in charge of gas investigations for the Bureau of Mines from 1908 until 1916, had analyzed natural gas from different fields and knew of its helium content. He had thought of helium as a possible filler for balloons and dirigibles and had mentioned the matter to F. A. Lidbury, of the Oldbury Chemical Co., and from him learned of Sir William Ramsay's interest in the subject and of the presence of helium-bearing gas in Canada. Prof. Satterly and Prof. Patterson, of the University of Toronto, began experiments looking to the separation of helium from Canadian natural gas Jan. 1, 1916. They used a Claude-system unit, at Hamilton, Ontario, but had much trouble in eliminating the heavier hydrocarbons of the natural gas.

Mr. Burrell was aware of the possibilities of the gases of the Petrolia field, in Texas, in regard to helium yield, and had samples sent to Dr. Cady for analysis. These samples contained about 1 per cent of the element. Thereupon, Mr. Burrell took up the question of utilizing this gas for helium recovery, with Dr. Cottrell and Dr. Moore, and the matter was discussed at length.

On May 12, 1917, Mr. Burrell wrote to Maj. C. DeF. Chandler (now Col. Chandler, of the Air Service), asking for an expression of opinion as to whether helium possessed sufficient advantages for use in balloons to warrant undertaking its production; and Messrs. Burrell and Moore, at the latter's suggestion, conferred with Maj. Chandler to ascertain whether the Army would consider furnishing the necessary funds for the project. G. O. Carter, of the Bureau of Steam Engineering of the Navy Department, learned from Maj. Chandler of this matter and became interested in it on behalf of the Navy Department.

At this time several conferences were held to discuss helium production from every angle, and opinions and views, all favoring it, were obtained from Dr. Cady, T. B. Ford, then in charge of the low-temperature laboratory of the Bureau of Standards, and O. P. Hood, chief mechanical engineer of the Bureau of Mines.

Dr. Cottrell advised Mr. Burrell to get in touch with Mr. Norton, for the possible employment of his process to separate helium from natural gas; accordingly, Mr. Norton was asked to come to Washington, where he arrived on June 4, 1917. Asked for a minimum estimate on the cost of a small experimental plant for the purpose, Mr. Norton estimated that a plant with a capacity of about 5,000 cu. ft. of helium a day, to try out his process, might be constructed for about $28,000. With this data in hand, the Director of the Bureau of Mines did his utmost to push the investigation. On July 19, 1917, he addressed a letter to the Chief Signal Officer of the War Department, requesting an allotment of $28,000 to try out the Norton process, and on July 20, 1917, Secretary Lane wrote to the Secretary of War on the same subject.

Dr. Moore had suggested to Dr. Cottrell that the Linde Air Products Co. and the Air Reduction Co., established firms in the business of gas liquefaction and separation, be brought into the helium undertaking, and in this suggestion Dr. Cottrell had heartily concurred. So these firms and one other (the Lacy process) were asked to cooperate with the Government, and developments finally culminated in a recommendation on July 26, 1917, by the Joint Army and Navy Airship Board, of an allotment of $100,000, in equal shares from Navy and Army appropriations, to make helium available as a substitute for hydrogen for balloons and airships. It was further recommended that arrangements be made with the Bureau of Mines to carry out the undertaking. On July 31, 1917, the Aircraft Production Board recommended that this be done.

About this time Capt. R. B. Owens, of the Signal Corps, went to England on a special mission. He had become very enthusiastic as regards helium, especially the possibilities of the Norton process, and took with him a letter from Mr. Burrell, which he presented to the British Admiralty. This led to the dispatch to this country of Commander C. D. C. Bridge and Lieut. Commander S. R. Locock, as a commission on behalf of the Admiralty to canvass the helium situation in this country and to investigate the Norton process. Through Vice Admiral Richard H. Peirse the Admiralty had written to Dr. R. A. Millikan (later Lieut. Col. Millikan), of the National Research Council, on July 25, 1917, that, on the strength of researches instituted by the Board of Inventions and Research, it had decided to fit up an experimental plant to investigate whether the use of helium for airships was practicable. The Admiralty was anxious to obtain from the United States 100,000,000 cu. ft. of the gas at once and to contract for a further supply of 1,000,000 cu. ft. a week, being particularly interested in the Norton process on account of the possibility of its greatly reducing the cost of producing helium, which the Admiralty feared would be prohibitive by the older, established processes. It was estimated that the best that could be expected from these older processes would be about $80 per 1,000 cu. ft.

Development of Plants for Helium Production

After the $100,000, mentioned previously, was allotted for helium work, the director of the Bureau of Mines placed Mr. Burrell in charge of the investigation. Mr. Norton started the design of a plant along the lines of his process, he and Mr. P. McD. Biddison, chief engineer of the Ohio Fuel & Supply Co., being appointed consulting engineers of the bureau. With others they made a field survey to determine the best site for operations. Dr. Cady was appointed consulting chemist on the staff of the Bureau of Mines; he and his assistants at the University of Kansas, particularly Dr. C. W. Seibel, did a large amount of analytical and research experimental work on helium, the results of which influenced the designs of the various helium plants that were constructed later. Dr. Cady also made valuable researches into the limits of inflammability of helium and hydrogen mixtures, and carried out a number of experiments on the permeability of balloon fabrics by helium.

The work in connection with the helium undertaking began at this time to assume such proportions and to broaden so much that Mr. Burrell felt that he would be unable to carry it on properly, his time being fully occupied with other pressing duties. Therefore, Prof. W. H. Walker, of the Massachusetts Institute of Technology, was asked to assume charge. This he did for a few weeks, and possibly it was at his suggestion that, for purposes of secrecy as a war measure, the name "argon" was substituted for helium and the three experimental plants finally constructed became known as "argon" plants. After Prof. Walker gave up this charge to become chief of the Chemical Service Section of the War Department, with the rank of lieutenant colonel, the helium work was carried on mainly by Dr. F. G. Cottrell in Washington and Mr. Norton and Mr. Biddison in the field, all under Dr. Manning's personal supervision, with Mr. Carter acting for the Navy and the Army, and the Linde Air Products Co. and the Air Reduction Co. cooperating so far as their processes were concerned. Contracts were closed with these two companies in Nov., 1917, and a contract was made with the Lone Star Gas Co., controlling the Petrolia field, for a supply of gas. Construction of a Linde plant and a Claude (Air Reduction Co.) plant was begun at Fort Worth, Tex., almost immediately after the contracts were executed. These plants, known respectively as "Argon Plants 1 and 2," were completed in March and in May, 1918. On May 11, 1918, Profs. Satterly and Patterson visited Fort Worth to inspect the plants and expressed themselves as highly pleased with what they saw. On Feb. 2, 1918, Dr. Manning assigned F. C. Czarnecki to Fort Worth as superintendent of the Linde and Claude plants; also, about the same time Mr. J. R. George, Jr., was assigned to assist Dr. Cottrell in Washington in conducting the helium work, with special reference to the Norton process. On Jan. 1, 1919, Dr. Andrew Stewart succeeded Mr. George. In the spring of 1919 Dr. L. H. Duschak was for some time associated with the helium project.

In June, 1918, the director of the Bureau of Mines placed

Dr. R. B. Moore in general charge of all three helium plants, as his personal representative. After visiting New York for consultation with the presidents of the Linde and the Air Reduction Cos. and to arrange for even closer cooperation of those corporations with the Government, Dr. Moore went to Worcester, where he conferred with Mr. Norton, and then went directly to Fort Worth. He has been actively connected with the helium work up to date, June, 1919.

The coming to this country of the British commission, in the fall of 1917, stimulated the interest of the Army and the Navy in helium. At a conference called by the director of the Bureau of Mines in his office, those present, besides Dr. Manning, were Commander Bridge, Lieut. Commander Locock, of the British commission; Prof. John Satterly, of the University of Toronto; Lieut. Commander Arthur H. Marks, Bureau of Construction and Repair, United States Navy; Capt. P. Pleiss, of the Signal Corps, United States Army; G. O. Carter, Bureau of Steam Engineering, United States Navy; Dr. W. H. Walker, Dr. C. L. Parsons, G. A. Burrell, P. McD. Biddison, F. E. Norton, Dr. Marston T. Bogert, National Research Council; W. W. Birge, president of the Air Reduction Co.; and Dr. B. S. Lacy. The helium project was discussed exhaustively and, as a result, recommendation was made that an appropriation of $500,000 be made available from Army and Navy funds, in equal shares, for four separate experimental plants, under the systems of Linde, Claude, Norton, and Lacy, respectively; that is to say, all systems recognized as practicable were to be given a trial. Later, the Lacy system was dropped. The recommendation was transmitted to the proper authorities of the Army and the Navy.

The $500,000 allotment was appropriated pursuant to a resolution of the Aircraft Production Board of Oct. 17, 1917, but, on the recommendation of the Navy Department, the Norton process was excluded from the benefits of any share thereof. This unexpected action was embarrassing both to the Bureau of Mines and to the British commission, but the Navy Department adhered to it and induced the War Department to take the same stand. Not until, at the Navy Department's insistence, the Norton process had been submitted to the searching examination of the National Research Council and that body had, by the unanimous action of a special committee, reported favorably on it Jan. 14, 1918, was a further sum of $100,000 made available for the Norton process, on Jan. 18, 1918. The special committee of the National Research Council was composed of Dr. Harvey N. Davis, of Harvard University; Dr. Edgar Buckingham and Dr. C. W. Waidner, of the Bureau of Standards; Dr. W. S. Landis, of the Air Nitrates Corporation; and S. L. G. Knox, consulting mechanical engineer, and later scientific attaché of the United States Embassy at Rome.

The Norton process is the latest practicable development in liquefying and separating gases. The Linde process (Plant No. 1) depends upon the so-called Joule-Thomson effect, obtained by the sudden expansion of a highly compressed gas through a small orifice, or nozzle, and the consequent cooling of the gas, the process being elaborated into a self-intensive or cumulative cycle of heat interchange by causing the cooled gas, on escaping, to circulate around the tube leading the initial gas into the apparatus.

George Claude, of Paris, conceived the idea of a liquefaction cycle with an expansion engine interpolated. Although the Joule-Thomson effect is used in the Claude cycle (Plant No. 2), its value is reduced to a minimum because the compression of the gas in this system is lowered. The maximum cooling effect is produced by the expansion engine because the compressed gas, on expanding in the engine cylinder, is made to do work and thus its temperature is lowered.

In the Norton process (Plant No. 3) three expansion engines are used, liquid is throttled, and the heat interchanger and fractionating still are of new design. In the Linde system an enormous expenditure of power is demanded to compress the gas in order to obtain the maximum effect of throttling, and this energy is then wasted. The Claude system requires much less compression power, but in this system the energy stored in the compressed gas is also dissipated. In the Norton system the requirement for gas compression is reduced to a minimum by the interpolation of the multiple-expansion engines, and what is needed is conserved and reapplied through the energy developed by these engines. Thus the maximum cooling effect is obtained at a minimum cost.

Construction of the Bureau of Mines (Norton process) plant, later known as Argon Plant No. 3, on the enlarged basis of a maximum production of 30,000 cu. ft. of helium a day, was begun on Apr. 3, 1918, and was completed Oct. 1, 1918. The cost was $148,398.29, the estimate for the plant enlarged to the proportions given having been $150,000. During the early construction work at this plant Mr. Biddison's services were of especial value; succeeding him, Apr. 20, 1918, George A. Orrok was appointed consulting engineer of the Bureau of Mines and has since been identified in this capacity with Plant 3.

The first site picked for the helium plants was at Fort Worth, Tex., selected by Messrs. Norton and Biddison, but later the Otto, Kans., region was deemed more advisable, as the natural gas there is exceptionally rich in helium; the supply, however, proved inadequate. The Bureau of Mines plant (Norton process) was then located at Petrolia, Tex., adjacent, for obvious reasons, to the properties of the Lone Star Co., but the plants of the Linde Co. and the Air Reduction Co., because of their requiring more water and more power, were built at Fort Worth, about 100 miles to the southeast, and were supplied with Petrolia gas through the Lone Star Co.'s pipe line.

The approximate cost of Plant No. 1 (Linde) was $245,000; that of Plant No. 2 (Air Reduction) was $135,000. The capacity of the first plant for producing 90 per cent helium from 0.4 per cent to 1 per cent helium-bearing natural gas, was 5,000 cu. ft. a day, and that of the second was 3,000 cu. ft. a day.

Plant No. 1 was the first to start, Mar. 6, 1918. Its production of helium began Apr. 8, 1918, when 27 per cent gas was obtained. Progressively better results were achieved until a purity of about 70 per cent on straight runs was reached. By reprocessing, the purity of this gas was raised to 92½ per cent. Plant No. 2 began to operate May 1, 1918, and on May 13 finally produced gas of 62 per cent to 70 per cent purity, which was reprocessed by Plant No. 1 to 92½ per cent. In all, about 200,000 cu. ft. of 92½ per cent helium has been produced by Plants 1 and 2. This gas has been stored in steel cylinders at a pressure of 2,000 lb. per sq. in., each cylinder containing about 200 cu. ft. expanded to atmospheric pressure. Of these cylinders 750 were ordered sent to France for aeronautic purposes and were on the dock at New Orleans awaiting shipment when the armistice was signed. They were returned to Fort Worth.

In order to coordinate properly all the different agencies concerned in the helium project, and to take steps for controlling effectively the exploration and conservation of helium, a committee consisting of one representative from each of the three governmental departments chiefly concerned was appointed by resolution of the Aircraft Board on Aug. 23, 1918. G. O. Carter, chairman, represented the Navy; Dr. Harvey N. Davis, the Army; and George A. Orrok, the Department of the Interior. Up to and including Oct. 23, 1918, there had been recommended and allotted from Army and Navy appropriations, in equal share, funds aggregating $1,090,000 for Plants 1, 2, and 3 and expenses incident to their maintenance and operation. The expenditure of this $1,090,000 has not only added vastly to human knowledge, but has supplied a commodity worth, at prewar prices, approximately from $250,000,000 to $400,000,000; and has prepared a war weapon for the United States of incalculable potency.

Construction of all three helium plants was carried out by the Constructing Quartermaster Corps of the Army, cooperating with the Bureau of Mines, and the finances of the helium undertaking have been handled by the finance division of the Bureau of Aircraft Production and the accounting section of the Bureau of Mines.

In Aug., 1918, the War and Navy Departments, realizing the paramount importance of insuring a supply of helium for military purposes, determined to build a large plant that would produce 30,000 cu. ft. of the gas a day. This plant, to be constructed along the lines of the Linde process, is to be situated at Fort Worth, Tex., and arrangements have been made for a lease of the Petrolia gas pool and for a Government pipe line to convey gas from Petrolia to Fort Worth.

On Dec. 8, 1918, the Aircraft Board submitted a report to the Secretary of War and the Secretary of the Navy, in which the change in the military situation because of the signing of the armistice was noted, the helium situation was re-

viewed, and recommendations for the future were made. Four different programs for further work on helium were submitted, that designated as Plan C being preferred. This was as follows:

Operation of Plant No. 3, for three months	$36,000
Construction of production Plant No. 1	1,700,000
Operation of production Plant No. 1 for 8 months, producing 7,200,000 cu. ft. helium	750,000
Pipe-line construction	1,800,000
Petrolia field lease	1,500,000
Total expenditures	$5,786,000
Salvage	500,000
Net cost	$5,286,000
Helium production, cu. ft.	7,200,000

On Dec. 17, 1918, the Director of the Bureau of Mines, in a letter to the Secretary of the Navy and the Secretary of War, submitted a report by the engineers of the bureau. This report outlined a plan similar to Plan C, but provided for further operation of all three experimental plants, also for a new Claude unit, and included a fund for conservation purposes. The bureau's engineers were convinced that the cost of producing helium had not been reduced to a mimimum and that undoubtedly in the long run money would be saved by perfecting producing methods through further experimental work. In any event, it was felt that something should be done toward conserving the Nation's helium supply.

On Dec. 27, 1918, the Secretary of the Navy wrote to the Director of the Bureau of Mines disapproving further experimental work by the Government, other than the small amount countenanced for Plant No. 3, under Plan C, and advising him of the adoption of Plan C. On Jan. 9, 1919, Maj. Gen. Jervey, of the General Staff of the Army, wrote advising that the War Department concurred in the action of the Secretary of the Navy and that the accomplishment of Plan C would be entrusted to the Navy Department.

Pursuant to this plan, the director of the Bureau of Mines ordered Plants 1 and 2 shut down on Jan. 23, 1919, but asked that Plant 2 be permitted to continue work, at its own expense, for a limited time in order to try out an improvement in its apparatus. On this basis, the Navy and War Departments consented to the further operation of Plant No. 2, the Navy agreeing to furnish gas of a higher helium content from its new pipe line (contemplated under Plan C) when this would be completed, about May, 1919.

The Bureau of Yards and Docks of the Navy Department took physical possession of Plant No. 2 and of the Government property of Plant No. 1, and assumed all expenses incurred by the Government incident to these plants as of Apr. 1, 1919. Plant 1 has been dismantled and the Linde Air Products Co. is to repurchase such of its apparatus and equipment as it agreed to do under its contract with the Bureau of Mines. All helium produced at these plants has been placed in the custody of the Navy Department at its special request.

Although only $36,000 was provided for further operation of Plant No. 3, under Plan C, a visit of inspection to this plant by Comdrs. H. N. Jenson and H. T. Dyer, Lieut. Comdr. Smith and G. O. Carter, on behalf of the Navy Department, about Mar. 15, 1919, so convinced the Navy officials of the exceptional merits of the Norton process and the possibilities of the plant in respect to producing high purity helium at a minimum cost that they became strongly in favor of affording it every opportunity to prove itself.

After overcoming many obstacles that could not be foreseen, Plant No. 3, on Apr. 2, 1919, began to produce helium, and by 5.30 a. m., Apr. 3, a purity of 19.8 per cent was reached. Helium production continued until that afternoon, when it became necessary to shut down for some minor repairs. On Apr. 17, 21 per cent helium was made, and it is confidently expected that helium of the highest purity will soon be produced by this plant on a large scale.

On Apr. 15, 1919, the Director of the Bureau of Mines called a conference in his office to discuss matters incident to the further operation of Plant 3 and kindred matters. There were present, besides the Director, Commander Jenson, representing the Navy; Col. C. DeF. Chandler, Col. A. L. Fuller, and Dr. H. N. Davis, representing the Army; and George A. Orrok, Fred E. Norton, L. H. Duschak, W. A. Ambrose, and Andrew Stewart, representatives of the Bureau of Mines. Fred E. Norton, who had come from Texas for the purpose, gave a detailed report on the operation of Plant No. 3 and described the need for alterations in and additions to its apparatus to insure the greatest possible efficiency. It was the sense of the meeting that liberal allotments of funds should be made for the continued experimental operation of the plant, with regard to its ultimately being run as a production unit. As a result of this conference, the Director of the Bureau of Mines recommended an allotment of $100,000 to make the alterations and acquire the equipment referred to. This fund has been made available, one-half by the Army and one-half by the Navy.

Cooperating Agencies

During the course of the work of the Bureau of Mines on processes of helium extraction, G. S. Rogers, of the United States Geological Survey, undertook a reconnoissance of the natural-gas fields in the United States with regard to their possible helium supply, so far as that might be judged by the analysis of samples of gas from existing wells and the study of geological conditions. In this work Dr. Cady and Dr. C. W. Seibel rendered valuable assistance in analytical investigations.

On Apr. 3, 1918, the petroleum division of the Bureau of Mines began work on the possible discovery of natural gas yielding helium, and from Apr. 3, 1918, to Jan. 1, 1919, conducted intermittently administrative work relating to the conservation of such natural gas. Examinations as to the possibility of obtaining helium in Montana, North Dakota, Washington, California, and southern Canada were made by C. H. Beal, J. O. Lewis, and A. W. Ambrose.

Following a conference between Dr. Cottrell and members of the staff of the Bureau of Standards, the Director of the Bureau of Mines, on Dec. 14, 1917, requested the Bureau of Standards to undertake the determination of certain physical properties of methane, especially with regard to its latent and specific heats and specific volumes over a wide range of pressures and temperatures. The purpose of this inquiry was to facilitate the experimental operation of the helium plants, in which liquid methane plays an important part.

Gluing Veneer at High Moisture Contents

It is common practice among plywood manufacturers to dry veneer down to very low moisture contents before gluing it. The object in doing so apparently is to prevent shrinkage of the veneer and consequent marring of the appearance of the finished panel. The drying is done in plate redriers, textile driers or similar apparatus, and adds appreciably to the cost of manufacturing panels.

That such preliminary drying may not be necessary is indicated by the results of a recent investigation by the Forest Products Laboratory. Veneer panels were glued with casein glue at various high moisture contents (some over 50 per cent) and in various tests proved as strong and as desirable as those made under drier conditions. In fact, in the moisture resistance tests a considerable proportion of the veneer which had been dried before gluing showed signs of failure, whereas veneer glued at a moisture content of 15 per cent or higher gave practically perfect results. Panels made at high moisture contents checked if dried too rapidly, but this difficulty could be avoided by proper operation of the kiln.

It seems possible, therefore, that the cost of producing panels of certain kinds may be very materially lessened through the use of water resistant glue and the reduction or even elimination of preliminary drying. Very dry veneer is more likely to break or split than damp veneer; an additional saving is therefore possible through a reduction of waste.

The use of moist veneer, of course, is not practicable for some purposes, but it is quite certain that much of the veneer which is now being painstakingly dried before gluing might advantageously be glued at a higher moisture content.—*Technical Note, Forest Products Laboratory.*

Radio Stations for Air Mail Service

The Post Office Department has contracted for three radio stations, the first of a chain of wireless communicating centres in various cities to be used primarily for the direction of mail-carrying airplanes handicapped by fog, it was announced in Washington July 10 by Emil J. Simon, manufacturer of radio apparatus.

Airplane and Seaplane Engineering*

By Commander H. C. Richardson, U. S. N.

One of the earliest floats tried at the model basin and built in full size was a twin float having a sharp V-bottom. The lines of this float conformed to the lines of a successful gunboat, and it was very pretty and clean in its action, but due to the influence of the curvature of the buttock lines at the stern, suction was present in this model and an airplane fitted with these floats, although able to get away with a pilot, was unable to get away with a pilot and passenger, there being insufficient reserve power to get over the hump.

Until very recently it was considered that so many inches of beam were required for every 100 lb. of weight carried by the float in order to attain planing, and this criterion has

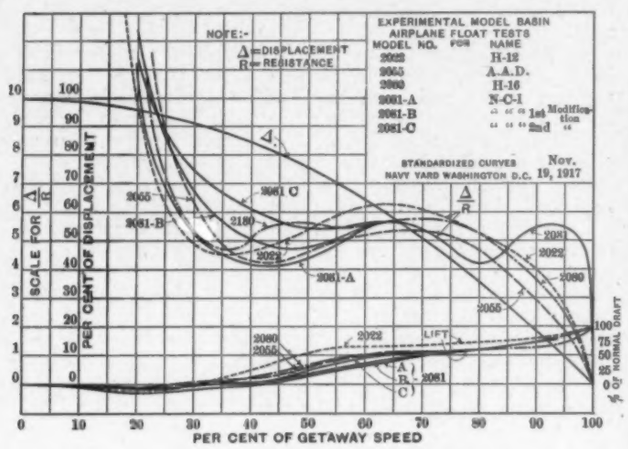


FIG. 5. RESULTS OF MODEL BASIN TESTS ON VARIOUS SEAPLANE FLOATS

led to the adoption of the great beam found in the F-5 and H-16 and HS-2 models. But experiments with floats suited to carry 1000 lb. each indicated that this model was remarkably satisfactory. The attempt was therefore made to enlarge this model in geometrical proportion to a 2000-lb float, and the model basin results indicated that this could be satisfactorily done. Another model was made of a 2000-lb. float and behaved satisfactorily. This same model was expanded to a 6000-lb float, which behaved even better than the original. The lines of the N-9 float, which has proved successful in our training program, were developed from the original 1000-lb. float, although this float had less beam than the original full-size float which was unsuccessful. As a result of these trials, I now consider it to be conclusively established that once a satisfactory float is developed for carrying a definite load under given conditions, the same design can be used for larger loads by merely expanding the original lines in the ratio of the cube root of the displacement ratios.

In the design of the float for the NC-1 this principle was used and the model tested in the model basin, although only one-twelfth full size, gave data which indicated satisfactory performance. These data have been closely verified by the actual performance of the NC-1, though many designers were skeptical that this float could handle its load on so narrow a beam. This is no greater than that used in the F-5; the F-5 carries a load of only 13,000 as against over 22,000 lb. carried by the NC-1.

Attention is now invited to Fig. 5, showing the results of model basin tests on a number of different models.

Results of Model Basin Tests Compared

The dimensions of the floats and the seaplanes they represented were so different that to get a comparison it has been necessary to plot these results on non-dimensional scales. It will therefore be noted that the displacement of the hull is plotted as a per cent of the total displacement based on a per cent of the get-away speed. The resistance of these floats is indicated by a plot of the ratio of the displacement to the resistance; also, based on the per cent of the get-away speed.

The resistance of No. 2081-A was nearly one-quarter of the displacement at 40 per cent of the get-away speed; the resistance of No. 2081-B was reduced to nearly one-fifth of the displacement at about 47 per cent of the get-away speed, and the resistance of No. 2081-C was between one-fifth and one-sixth of the displacement at about 52 per cent of the get-away speed. Also, the displacement in the latter case is less than in the preceding cases.

This change was brought about as follows: The original form of float had two steps, with curvature in the middle

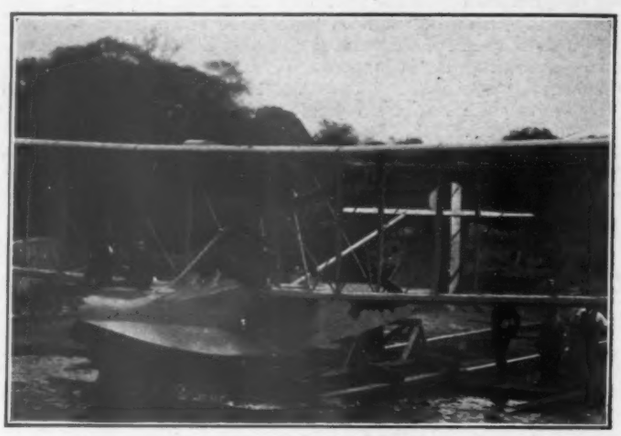


FIG. 6. HS-2L SEAPLANE

step and a rank up-curvature in the rear step. No. 2081-B represents this model with the rear step straightened, and No. 2081-C represents this float with straight lines for the bottom abaft the first step. It will readily be seen that the first modification was an improvement over the original, and the second modification was a still greater improvement. These models represent the model of the NC-1, and there is no doubt in my mind that if the original model had been used this seaplane could not have got off the water. Further, the influence of the curved portion at the tail of the float would have been so great as to cause the machine to squat so badly that the tail surfaces would have been caught in the stream of water rising from the tail of the float.

Let us now return to the horsepower curves. It will be noted that the resistance of this seaplane float reaches a maximum at a speed of 20 mi. per hr., which speed corresponds to the point at which planing begins, and that there is a secondary hump at a speed of 40 miles per hr. The get-away speed is assumed as 62 mi. per hr. The horsepower curve has been directly derived from the resistance of the float, and this horsepower must be compounded with that of the airplane progressing through the air. The horsepower required for this purpose is determined by taking the horsepower of the airplane at 62 mi. per hr., which in this case is 150 e.hp., and noting that the horsepower for the wings and head resistance is proportional to the cube of the speed. We thus derive the curve of the total air e.hp. required for the seaplane, which must be compounded with the horsepower required for the float, thus giving us a total horsepower curve for the seaplane for speeds below the get-away speed, that is, while still in the water.

From an inspection of the horsepower curves, it will be seen that the maximum horsepower for the float is required at a speed of about 23 mi. per hr., and that this, compounded with the horsepower due to air resistance, requires 88 hp. at this speed.

The horsepower for planing is very little exceeded by the horsepower available, so that it would take a relatively long

* Excerpt from a paper read at the annual meeting of the Society of Automotive Engineers. Concluded from last issue.

time to pass through the planing condition; but, after this point is passed, the seaplane should accelerate rapidly because the reserve of horsepower available rapidly increases up to the get-away speed.

There is a secondary hump in the horsepower curve at 60 mi. per hr. just before the get away is attained, but this secondary hump is of little importance as there is an ample reserve of horsepower at this point.

As a matter of interest, I have investigated the improvement in performance which could be expected if a geared-down engine were used, assuming a ratio of 0.6; that is, the propeller turning at 0.6 of the revolutions of the engine. With this gear ratio a propeller 13 ft. in diameter is indicated. Such a propeller at a speed of 80 mi. per hr. would show

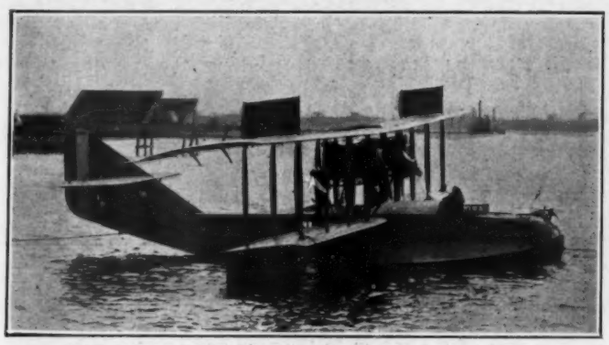


FIG. 7. H-16 SEAPLANE

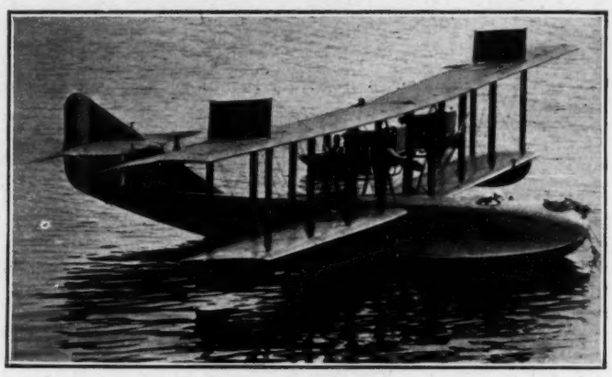


FIG. 8. F-5-L SEAPLANE

an efficiency of 73 per cent as against 69 per cent for the 9-ft. diameter propeller. This gain of 4 per cent at 80 mi. per hr. would increase the climb by more than 11 per cent. It would have little effect on the speed, as the horsepower curve is very steep in this region. The improvement in efficiency at 20 mi. per hr., although only 6 per cent would mean an increase of 200 per cent in the reserve of horsepower to get over the hump in the horsepower curve at that speed. You will therefore see why in naval work the use of the geared-down propeller offers considerable advantage. The substitution of the geared-down Liberty for the straight-drive Liberty engines in the F-5 changes the top speed of this seaplane from 90 to 100 mi. per hr. and makes the get away of this seaplane certain and rapid under all conditions, whereas the straight-drive propellers were only able to get this boat with great difficulty in a calm.

The V-Bottom versus the Flat

Experiments have recently been made at the model basin on a series of models having different angles of V-bottom from the flat bottom up to a 20-deg. V, and it is found that from a resistance point of view there is very little difference in the performance of the four models tried. So far as any advantage is shown, the deep-angle V has slightly the best of the argument. From a service point of view the deep V-bottom has many advantages; among them its remarkable shock-absorbing properties in taking care of bad landings, or in getting away and landing on a rough sea. The V-bottom also permits landing across the wind without serious retardation and without danger of capsizing sideways. This type of hull appears to absorb the shock by penetration and reduces the loads imposed on the bottom planking and on the framing supporting this. Due to this feature there is no need of carrying shock absorbers between the floats and the rest of the plane structure, and the lightest possible construction can be adopted.

The first hulls built in this country had an elaborate framework of ribs and longitudinals supporting the bottom planking, which afforded a regular network having hundreds of intersections requiring fastening, the fastenings themselves weakening the frames and the longitudinals at the point where the frames carried concentrated loads on small areas of side grain. This type of construction was unnecessarily heavy and costly and was early abandoned in the construction of pontoons of navy design in favor of the longitudinal system of support.

In the longitudinal system of support the inner ply of planking is run athwartship and thereby constitutes a continuous system of ribs. This system is further reinforced by the outer planking run 45 deg. to the keel, which also acts as a continuous system of ribs, and these two systems transmit the water pressure as a distributed loading to the longitudinal members, which do not have their strength robbed by a series of notches. The longitudinals are arranged so that they collect the distributed load and concentrate it at points of support in athwartship bulkheads and these bulkheads in turn distribute the load to the keel, to the chine stringers, and to the deck planking. The keel itself is usually associated with a center longitudinal truss. Through these members the load is finally distributed to struts or directly to the wing structure.

On a large scale this system is adopted in the construction of the hull of the NC-1 which, although it embodies other features than those necessary to support the bottom planking, weighs only 2600 lb. while it carries a load of 22,000 lb. This hull has demonstrated ample strength in landing on and getting off an 8-ft. cross sea in practically dead air, where the landing and get away were both made under the hardest conditions.

CHARACTERISTICS OF THE PRINCIPAL NAVAL FLYING BOATS

Type	HS-2-L	H-16	F5-L	NC-1
Weight, fully loaded, lb.	6,432	10,900	13,000	22,000
Useful load, lb.	2,132	3,500	4,750	7,750
Maximum speed, miles per hr.	91	95	87	81*
Minimum speed, miles per hr.	55	56	57	61†
Initial climb, ft.	2,500 to 3,000 in 10 min.	3,000 in 10 min.	2,625 in 10 min.	1,050‡ in 5 min
Over-all span, ft.-in.	74 0 19/32	95 0 13/16	103 9 1/4	126 0
Over-all length, ft.-in.	38 5 15/16	46 1 15/32	49 3 11/16	68 2 29/32
Over-all height, ft.-in.	14 7 1/4	17 8 5/8	18 9 1/4	24 6
Chord, ft.-in.	6 3 5/32	7 0 49/64	8 0	12 0
Wing area, sq. ft	803	1,164	1,397	2,380
Hull length, ft.-in.	34 3	42 3	....	44 7

A controversy has existed for years as to the merits of the single float as compared with the twin float, but, based on the experience of our Navy with examples of both types, I believe that the central float with wing tip balancing floats is decidedly the better arrangement. In the central float system the loads can be concentrated on the point of support, whereas in the twin-float system the loads are usually concentrated in the center of the span and the wing structure has to be utilized to gain the necessary stiffness and necessarily has to be made heavier. In the center-float type if a single propeller is used it is located above the float and protected from the water, whereas in the twin-float type such pro-

* Carrying a load of 21,560 lb.
† Carrying a load of 21,569 lb.
‡ At a speed of 67 miles per hr. with a load of 21,318 lb.

peller necessarily swings over the gap between the floats, which subjects it to punishment by spray and broken water. In landing a twin-float seaplane, unless both floats arrive at the same time, the second float invariably strikes harder than the first, being slammed down on the water. Due to the greater lateral stiffness of the twin-float system, when geting off rough water the seaplane is forced to conform in its attitude to the form of the surface and wracks and lurches violently sideways unless going directly across the crest of the sea. In maneuvering in the air, also, the separation of the twin floats adds considerably to the inertia about the longitudinal axis and makes the action of the ailerons less effective. With twin floats, when taxi-ing across a strong side wind the lee float must have at least 100 per cent reserve buoyancy, and this leads to greater weight than is necessary with the single center-float providing the same stability.

Types of Navy Planes

As above referred to, the principal types of service planes used by the Navy were the HS-2, H-16 and F-5.

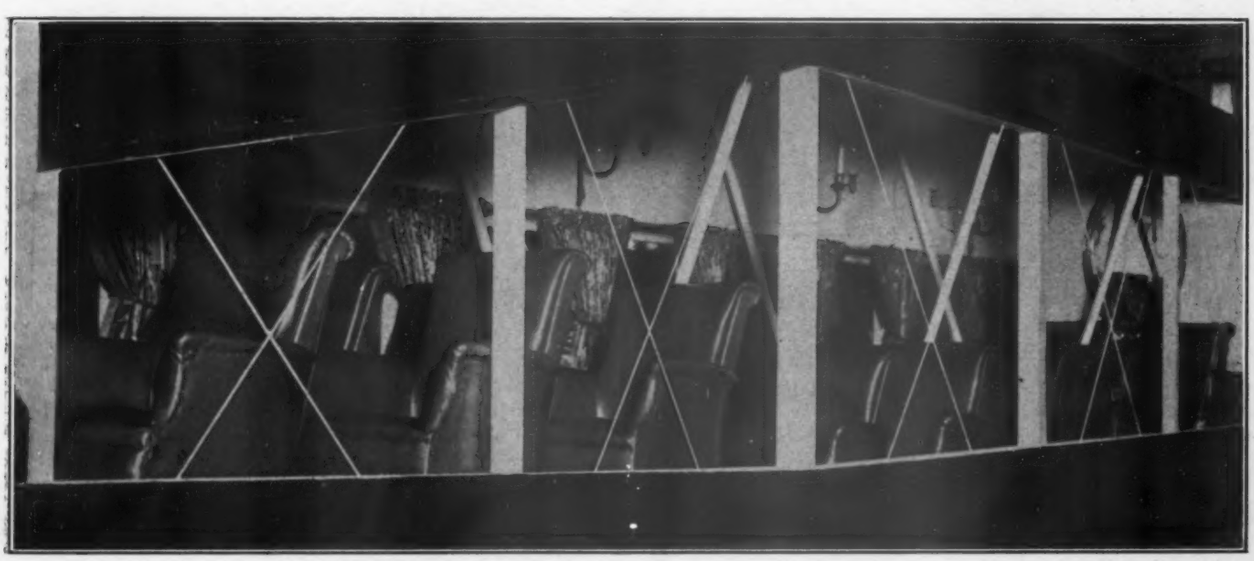
The HS-2 was developed from an original twin-motored seaplane designed for the Army, which, however, did not prove successful. It was originally intended to be used with two 100-hp. engines. Later, when the Navy tood hold of it, the Curtiss VX3, a 200-hp. engine was used, and this seaplane gave a fairly satisfactory performance with this powerplant. At about the same time the Liberty engine became available, and as soon as it was installed it was found that this performance was very much improved and this seaplane was capable of flying at a total weight of about 5900 lb. On this basis it was then attempted to convert it into a military machine by providing the necessary guns, bombs and other equipment. After everything had been added, it was found impracticable to carry the military load desired on a limit of 5900 lb. total weight. The expedient was therefore adopted of adding wing surface, and the original HS-1 thus became the HS-2, capable of carrying a load of 6500 lb. with practically no reduction in full speed and with considerable increase in climbing power. Many forced landings have been made at sea; some due to powerplant difficulties, such as stoppage of fuel supply, or failure of the engine or propeller, and sometimes due to head winds forcing a landing on a return trip on account of exhaustion of fuel. Although many of these landings were made under bad weather conditions and in rough seas, in nearly every case landings were accomplished without serious damage to the hull.

The general arrangement of this seaplane is indicated in Fig. 6. The pilot and assistant pilot are seated in a cockpit just forward of the wings, from which point they have a good view for the operating of the seaplane. A radio outfit is provided just forward of the pilot. A gunner's cockpit is fitted in the bow, and this cockpit is provided with a gun ring and Lewis gun. This gunner has a very good range of fire, particularly ahead and down and on either beam; also upward and to the rear above the planes. But there are no means of firing abaft the beam, and the boat is unprotected against attack from the rear. In the gunner's cockpit are also fitted the bomb pulls and the sight for dropping the bombs, which are located under the wings just clear of the hull. On account of its undefended condition against attack from the rear, this seaplane was not used in sectors where it would be exposed to attacks by enemy aircraft, but there were many places abroad—and, of course, in this country—where no such attack was probable and where it proved particularly useful in submarine patrol and convoy work. This seaplane is also used for instruction purposes as an advanced step toward handling the regular twin-motored seaplanes. The HS-2 is provided with a single Liberty engine and a pusher propeller, and has very satisfactory air maneuvering qualities.

The H-16 (shown in Fig. 7) was a twin-engined seaplane with a flying-boat hull, using tractor propellers. The pilot and observer are seated in a cockpit about half-way between the bow and the wings, where they have an excellent view. The H-16 was also fitted with a gunner's cockpit the same as the HS-2. In addition, a wireless operator was carried inside the hull just forward of the wings and back of the pilots. Abaft the wings an additional gun ring was fitted covering the arc of fire above and between the wings and the tail controls and to take care of the region to the rear and below the tail controls; gun mounts were also fitted, swinging on brackets through side doors in the hull. The bomb gear was operated from the forward gunner's cockpit and four bombs were carried, two under either wing. This type of boat proved very serviceable, and was a substantial copy of the same type of boat built in this country for England, differing only in minor details from those supplied to England. This boat was really a successor to the H-12, which was very similar, except that the hull of the H-12 was more like that of the HS-2 both in construction and in the form of the planing fins.

The F-5, shown in Fig. 8, is very similar to the H-16, being approximately 10 per cent larger than the H-16. In addition to this increase in dimensions, which was made to afford a great military load, it will be noted that this seaplane has balanced wing tip ailerons and also a balanced rudder. The hull form is practically identical with that of the H-16. The principal data of all three of these boats will be found in the accompanying table.

Modern Aerial Transport



Passenger Accommodation of a 1600 Hp. Handley-Page

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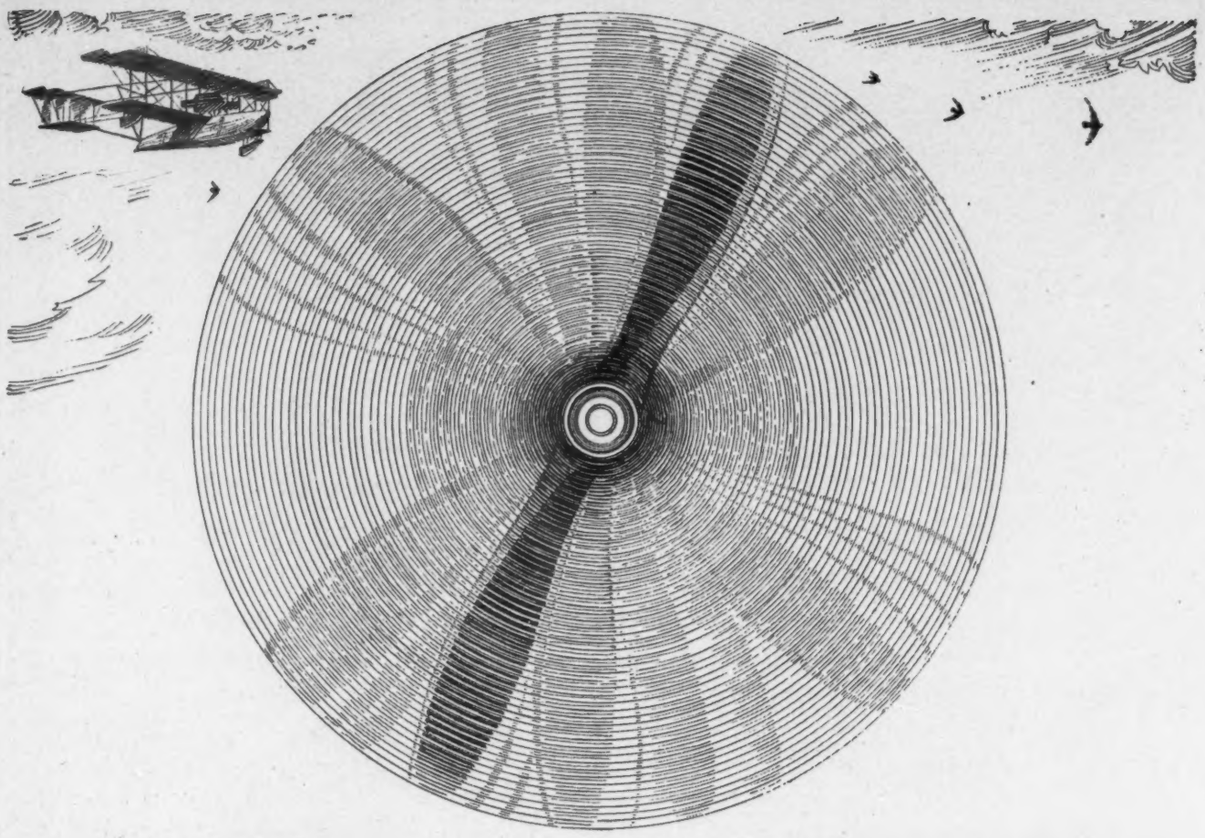

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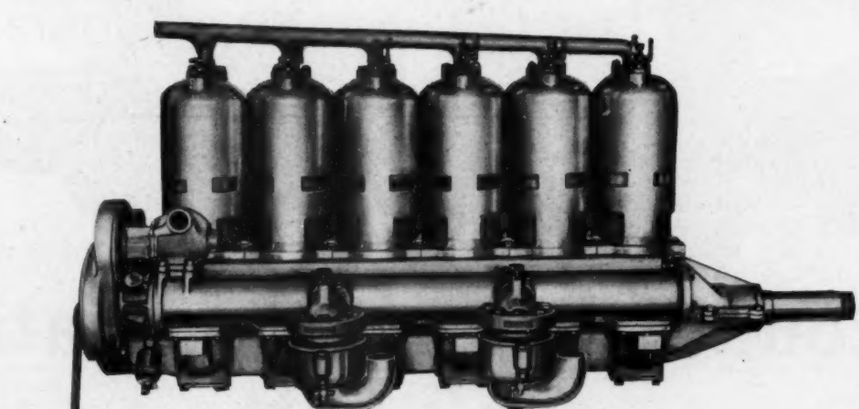

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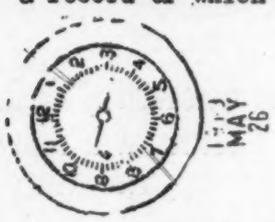

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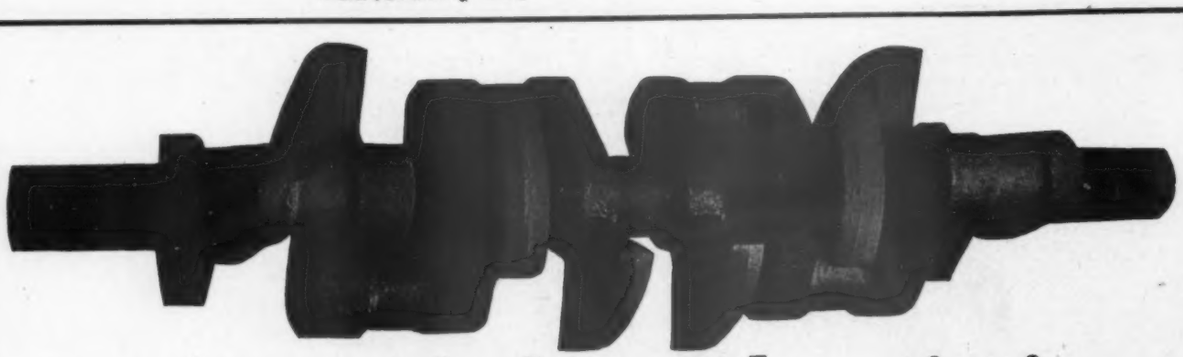

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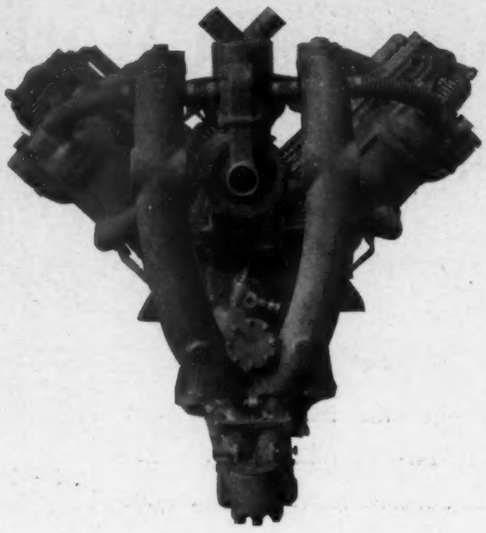

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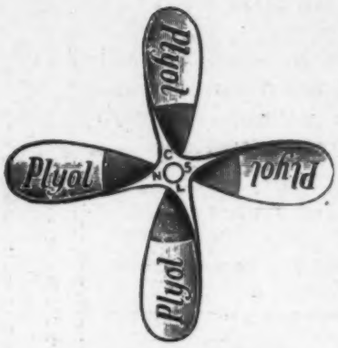

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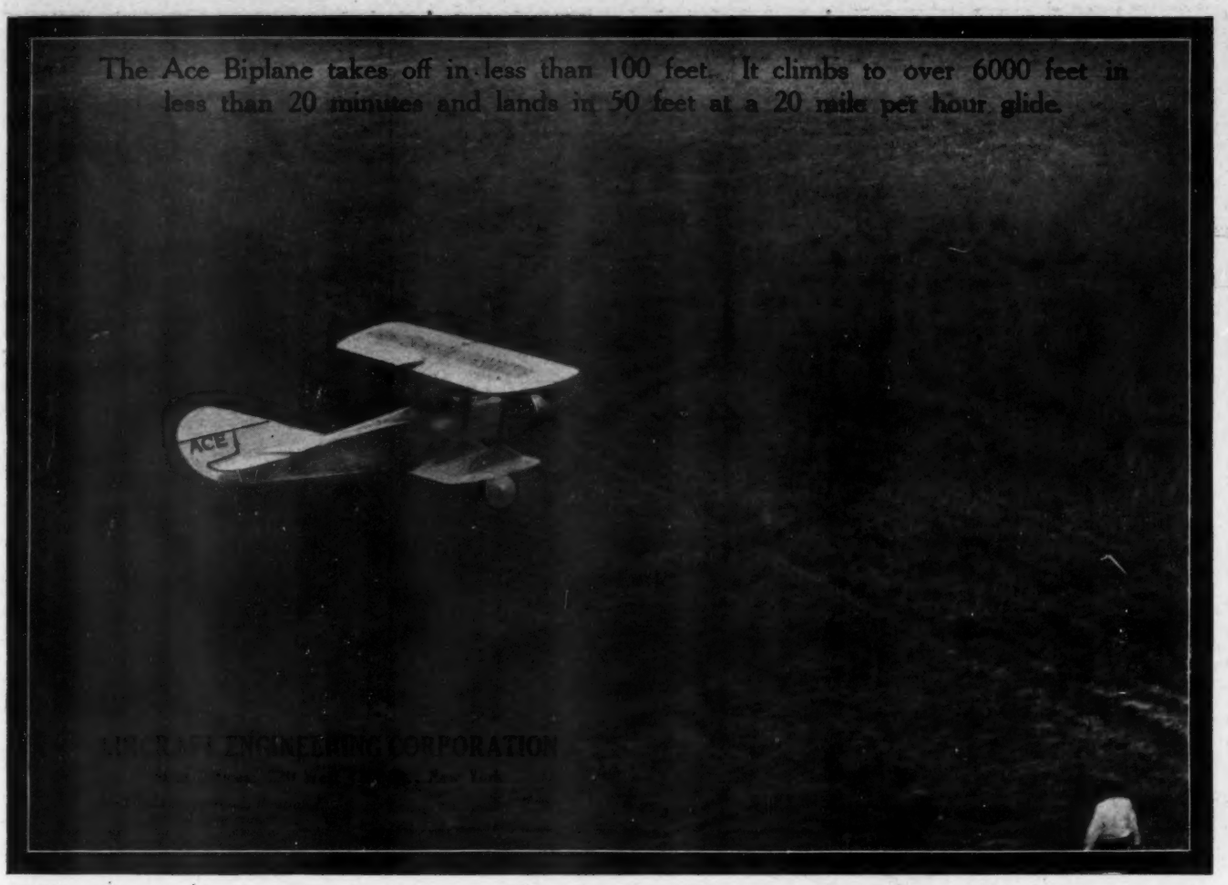
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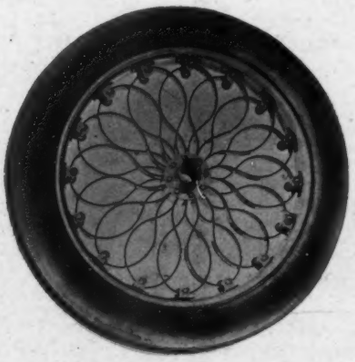

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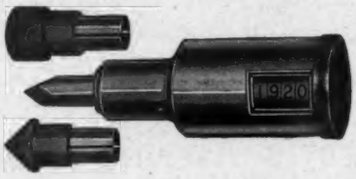

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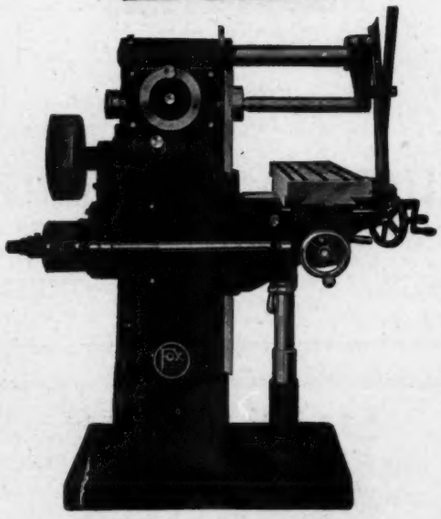

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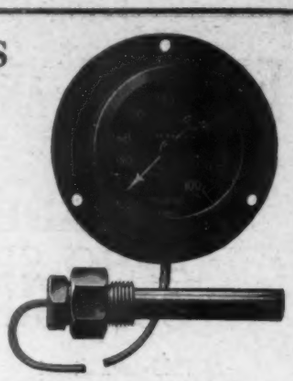

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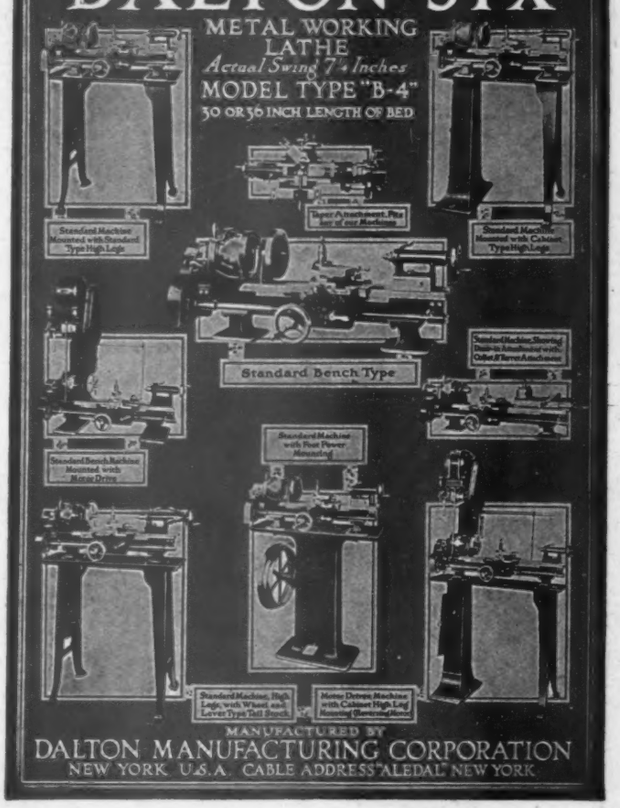

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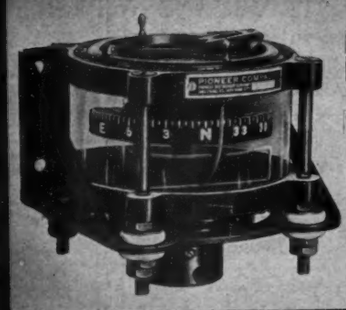

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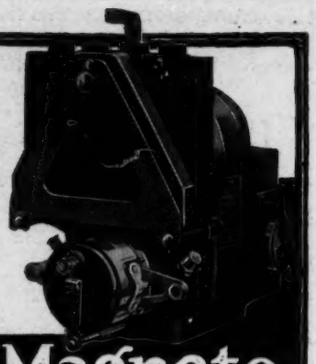

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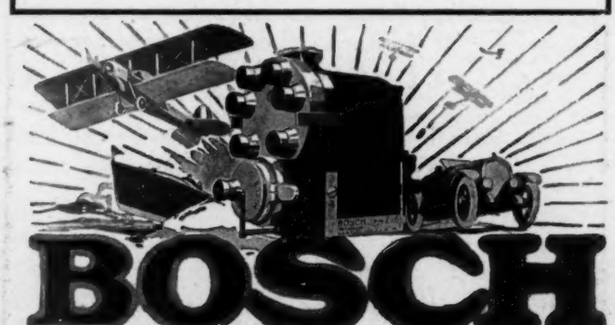

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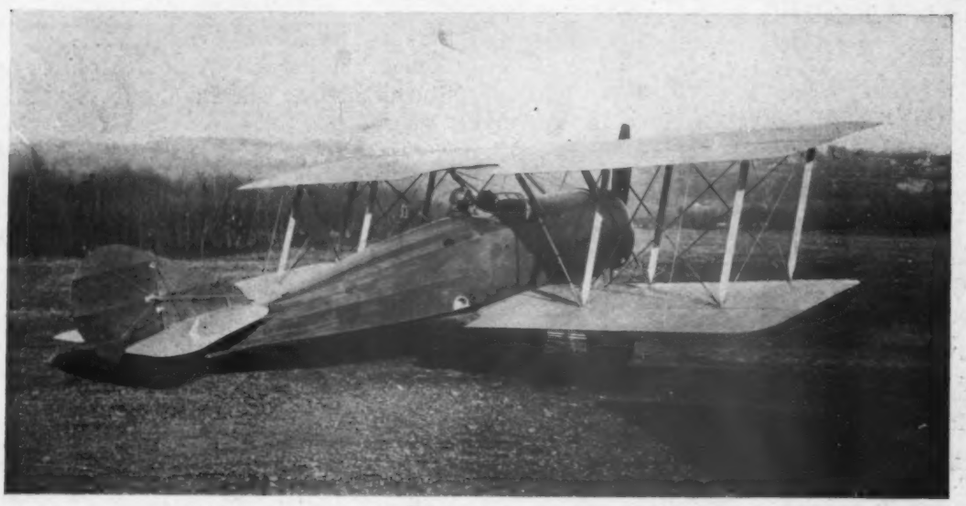

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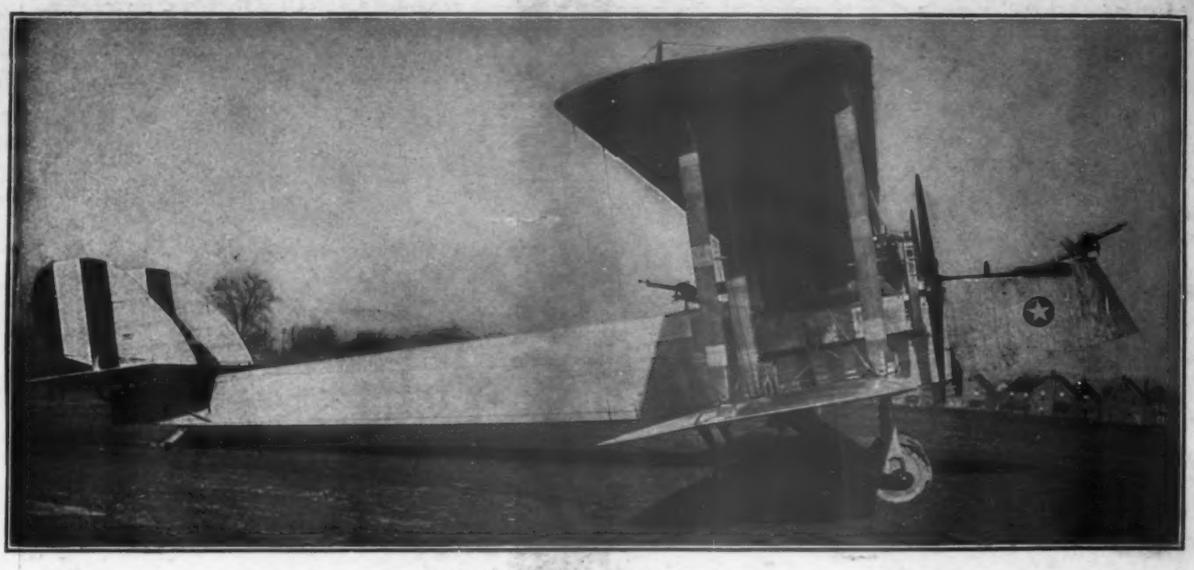

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